4TH EDITION

# COGNITIVE PSYCHOLOGY

## In and Out of the Laboratory

Kathleen M. Galotti

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# Cognitive Psychology

## In and Out of the Laboratory

Fourth Edition

Kathleen M. Galotti
*Carleton College*

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*for Timmy and Kimbie, for making it all worth doing;*
*and*
*for Tandy, Bussey, Eskie, Flit, and Tackle, who have taught so much and asked so little in return*

# About the Author

Kathleen M. Galotti holds a B.A. in psychology and economics from Wellesley College, as well as an M.A. and a Ph.D. in psychology and an M.S.E. in computer and information sciences from the University of Pennsylvania. At Carleton College she is a full professor of psychology and cognitive studies. She serves as the director of an interdisciplinary program in cognitive studies, a program she helped establish in 1989. She also is a former department chair of psychology. She teaches courses in introductory psychology, statistics, and cognitive and developmental psychology.

Dr. Galotti is the author or coauthor of dozens of studies in cognitive and developmental psychology. Her research centers on the development of reasoning and decision-making skills from the preschool period through adulthood and on the styles with which adolescents and adults plan for the future, make important life commitments, and learn new information. Her research has been funded through the National Science Foundation, the Spencer Foundation, and the National Institutes of Health. She is the author of *Making Decisions That Matter: How People Face Important Life Choices* (Erlbaum, 2002).

Dr. Galotti is the parent of two children, Timothy and Kimberlynn, and spends much of her time enjoying their youthful exuberance and energy. In her spare time, she raises and trains Bernese mountain dogs, shows them in competition in licensed obedience trials, and is a licensed obedience judge for the American Kennel Club.

# Brief Contents

PART I
Overview 1
1 ■ Cognitive Psychology: History, Methods, and Paradigms 2
2 ■ The Brain: An Overview of Structure and Function 35

PART II
Basic Processes 55
3 ■ Perceiving Objects and Recognizing Patterns 56
4 ■ Paying Attention 104
5 ■ Forming and Using New Memory Traces 149
6 ■ Retrieving Memories From Long-Term Storage 183

PART III
Representation and Organization of Knowledge 233
7 ■ Memory for General Knowledge 234
8 ■ Concepts and Categorization 267
9 ■ Visual Imagery and Spatial Cognition 295

PART IV
Use and Manipulation of Information 335
10 ■ Language 336
11 ■ Thinking and Problem Solving 386
12 ■ Reasoning 422
13 ■ Making Decisions 459

PART V
Individual and Situational Differences in Cognition 497
14 ■ Cognitive Development Through Adolescence 498
15 ■ Individual, Aging, and Gender Differences in Cognition 538
16 ■ Cognition in Cross-Cultural Perspective 573

Glossary 616
References 629
Author Index 660
Subject Index 671

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# Contents

## Part I Overview 1

### CHAPTER 1

### Cognitive Psychology: History, Methods, and Paradigms 2

Influences on the Study of Cognition 5
- *Structuralism* 6
- *Functionalism* 7
- *Behaviorism* 9
- *Gestalt Psychology* 10
- *Genetic Epistemology* 11
- *The Study of Individual Differences* 12
- *The "Cognitive Revolution"* 14
- *Current Trends in the Study of Cognition* 17
- *General Points* 18

Research Methods in Cognitive Psychology 19
- *Naturalistic Observation* 19
- *Introspection* 20
- *Controlled Observation and Clinical Interviews* 21
- *Experiments and Quasi-Experiments* 21
- *Investigations of Neural Underpinnings* 22
- *General Points* 22

Paradigms of Cognitive Psychology 24
- *The Information-Processing Approach* 24
- *The Connectionist Approach* 26
- *The Evolutionary Approach* 28
- *The Ecological Approach* 29
- *General Points* 31

SUMMARY 32

REVIEW QUESTIONS 33

KEY TERMS 33

COGLAB DEMONSTRATIONS 34

WEB RESOURCES 34

CHAPTER 2

The Brain: An Overview of Structure and Function 35

Structure of the Brain 36
- *The Hindbrain and Midbrain* 36
- *The Forebrain* 38

Localization of Function 41

Lateralization of Function 46

Brain Imaging Techniques 47

SUMMARY 53

REVIEW QUESTIONS 53

KEY TERMS 54

COGLAB DEMONSTRATIONS 54

WEB RESOURCES 54

Part II Basic Processes 55

CHAPTER 3

Perceiving Objects and Recognizing Patterns 56

Gestalt Approaches to Perception 59

Bottom-Up Processes 64
- *Template Matching 65*
- *Featural Analysis 68*
- *Prototype Matching 75*

Top-Down Processes 79
- *Perceptual Learning 82*
- *Change Blindness 84*
- *The Word Superiority Effect 87*
- *A Connectionist Model of Word Perception 88*
- *A Neuroscientific Perspective on Word Perception 91*

Direct Perception 92

Disruptions of Perception: Visual Agnosias 97

SUMMARY 100
REVIEW QUESTIONS 101
KEY TERMS 102
COGLAB DEMONSTRATIONS 102
WEB RESOURCES 103

**CHAPTER 4**
**Paying Attention 104**

Selective Attention 107
- *Filter Theory 109*
- *Attenuation Theory 114*
- *Late-Selection Theory 115*
- *Attention, Capacity, and Mental Effort 116*
- *Schema Theory 119*
- *Inattentional Blindness 120*

Neuroscientific Studies of Attention 123
- *Networks of Visual Attention 125*
- *Event-Related Potentials and Selective Attention 127*

Automaticity and the Effects of Practice 128
- *The Stroop Task 128*
- *Automatic Versus Attentional (Controlled) Processing 129*
- *Feature Integration Theory 135*
- *Attentional Capture 136*

Divided Attention 137
- *Dual-Task Performance 137*
- *The Attention Hypothesis of Automatization 139*
- *The Psychological Refractory Period (PRP) 140*
- *Divided Attention Outside the Laboratory: Cell Phone Usage While Driving 144*

SUMMARY 146
REVIEW QUESTIONS 147
KEY TERMS 148
COGLAB DEMONSTRATIONS 148
WEB RESOURCES 148

**CHAPTER 5**
**Forming and Using New Memory Traces 149**

Metaphors of Memory 151

Sensory Memory 154
- *The Icon 154*
- *The Echo 156*

Short-Term Memory 159
- *Capacity 159*
- *Coding 160*
- *Retention Duration and Forgetting 161*
- *Retrieval of Information 165*

Working Memory 169

Executive Functioning 174

Neurological Studies of Memory Processes 175

SUMMARY 179
REVIEW QUESTIONS 180

KEY TERMS 181
COGLAB DEMONSTRATIONS 181
WEB RESOURCES 182

CHAPTER 6
Retrieving Memories From Long-Term Storage 183

The Traditional View of Long-Term Memory 184
- *Capacity* 184
- *Coding* 185
- *Retention Duration* 186
- *Forgetting* 187
- *Retrieval of Information* 194

The Levels-of-Processing View 198

The Reconstructive Nature of Memory 202
- *Autobiographical Memory* 204
- *Flashbulb Memories* 207
- *Eyewitness Memory* 211
- *The Recovered/False Memory Debate* 214

Amnesia 220
- *Anterograde Amnesia* 221
- *Retrograde Amnesia* 223

SUMMARY 227
REVIEW QUESTIONS 229
KEY TERMS 230
COGLAB DEMONSTRATIONS 230
WEB RESOURCES 231

Part III Representation and Organization of Knowledge 233

CHAPTER 7
Memory for General Knowledge 234

The Semantic/Episodic Distinction 236

Semantic Memory Models 239
- *The Hierarchical Semantic Network Model* 240
- *The Feature Comparison Model* 245
- *Other Network Models* 248
- *The ACT Models* 250
- *Connectionist Models* 252

Schemata 255
- *Scripts* 257

Implicit Versus Explicit Memory 258
- *The Process Dissociation Framework* 261

SUMMARY 264
REVIEW QUESTIONS 265
KEY TERMS 266
COGLAB DEMONSTRATIONS 266
WEB RESOURCES 266

CHAPTER 8
Concepts and Categorization 267

Theoretical Descriptions of the Nature of Concepts 270
- *The Classical View* 270
- *The Prototype View* 272
- *The Exemplar View* 277
- *The Schemata View* 278
- *The Knowledge-Based View* 279

Forming New Concepts and Classifying New Instances 281
- *Concept Attainment Strategies* 281
- *Acquiring Prototypes* 284
- *Implicit Concept Learning* 285
- *Using and Forming Scripts* 290
- *Psychological Essentialism* 291

SUMMARY 292
REVIEW QUESTIONS 293
KEY TERMS 294
COGLAB DEMONSTRATIONS 294
WEB RESOURCES 294

## CHAPTER 9

## Visual Imagery and Spatial Cognition 295

Mnemonics and Memory Codes 297
- *Mnemonics* 297
- *The Dual-Coding Hypothesis* 300
- *The Relational-Organizational Hypothesis* 301

Empirical Investigations of Imagery 302
- *Mental Rotation of Images* 304
- *Scanning Images* 309

The Nature of Mental Imagery 315
- *Principles of Visual Imagery* 315
- *Critiques of Mental Imagery Research and Theory* 319

Neuropsychological Findings 324

Spatial Cognition 326

SUMMARY 331

REVIEW QUESTIONS 332

KEY TERMS 332

COGLAB DEMONSTRATIONS 333

WEB RESOURCES 333

Part IV Use and Manipulation of Information 335

CHAPTER 10

Language 336

The Structure of Language 339
- *Phonology* 341
- *Syntax* 343
- *Semantics* 348
- *Pragmatics* 349

Language Comprehension and Production 351
- *Speech Perception* 351
- *Speech Errors in Production* 356
- *Sentence Comprehension* 357
- *Comprehending Text Passages* 360
- *Story Grammars* 367
- *Gricean Maxims of Conversation* 369

Language and Cognition 373
- *The Modularity Hypothesis* 374
- *The Whorfian Hypothesis* 375
- *Neuropsychological Views and Evidence* 379

SUMMARY 382

REVIEW QUESTIONS 384

KEY TERMS 384

COGLAB DEMONSTRATIONS 385

WEB RESOURCES 385

CHAPTER 11

Thinking and Problem Solving 386

Classic Problems and General Methods of Solution 390
- *Generate-and-Test Technique* 390
- *Means–Ends Analysis* 392
- *Working Backward* 394
- *Backtracking* 395
- *Reasoning by Analogy* 396

Blocks to Problem Solving 399
- *Mental Set* 399
- *Using Incomplete or Incorrect Representations* 402
- *Lack of Problem-Specific Knowledge or Expertise* 405

The Problem Space Hypothesis 407

Expert Systems 411

Finding Creative Solutions 413
- *Unconscious Processing and Incubation* 414
- *Everyday Mechanisms* 415

Critical Thinking 417

SUMMARY 419

REVIEW QUESTIONS 420

KEY TERMS 421
COGLAB DEMONSTRATIONS 421
WEB RESOURCES 421

**CHAPTER 12**
**Reasoning 422**

Types of Reasoning 424
  *Deductive Reasoning 425*
  *Inductive Reasoning 431*
  *Everyday Reasoning 434*

Patterns of Reasoning Performance 436
  *Effects of Premise Phrasing 436*
  *Alteration of Premise Meaning 437*
  *Failure to Consider All Possibilities 439*
  *Content and Believability Effects 439*
  *Biases 442*

Three Approaches to the Study of Reasoning 442
  *The Componential Approach 443*
  *The Rules/Heuristics Approach 446*
  *The Mental Models Approach 450*

Neuropsychological Evidence on Reasoning 454

SUMMARY 456
REVIEW QUESTIONS 457
KEY TERMS 457
COGLAB DEMONSTRATIONS 458
WEB RESOURCES 458

**CHAPTER 13**
**Making Decisions 459**

Phases of Decision Making 461
  *Setting Goals 462*
  *Gathering Information 462*
  *Structuring the Decision 462*
  *Making a Final Choice 463*
  *Evaluating 464*

Basic Concepts of Probability 464

Cognitive Illusions in Decision Making 466
  *Availability 467*
  *Representativeness 469*
  *Framing Effects 472*
  *Anchoring 473*
  *Sunk Cost Effects 474*
  *Illusory Correlation 474*
  *Hindsight Bias 476*
  *Confirmation Bias 478*
  *Overconfidence 479*

Utility Models of Decision Making 481
  *Expected Utility Theory 481*
  *Multiattribute Utility Theory 484*

Descriptive Models of Decision Making 488
  *Image Theory 489*
  *Recognition-Primed Decision Making 490*

Improving Decision Making 491

SUMMARY 493
REVIEW QUESTIONS 495
KEY TERMS 495
COGLAB DEMONSTRATIONS 496
WEB RESOURCES 496

**Part V Individual and Situational Differences in Cognition 497**

**CHAPTER 14**
**Cognitive Development Through Adolescence 498**

Piagetian Theory 500
  *General Principles 501*
  *Stages of Development 503*
  *Reactions to Piaget's Theory 511*

Non-Piagetian Approaches to Cognitive Development 512

- *Perceptual Development in Infancy* 514
- *Toddlers' Acquisition of Syntax* 515
- *Preschoolers' Use of Memorial Strategies* 519
- *Conceptual Development in Early Childhood* 520
- *The Development of Reasoning Abilities in Middle and Late Childhood* 522

Some Post-Piagetian Answers to the Question "What Develops?" 524
- *Neurological Maturation* 524
- *Working-Memory Capacity and Processing Speed* 526
- *Attention and Perceptual Encoding* 527
- *The Knowledge Base and Knowledge Structures* 529
- *Strategies* 532
- *Metacognition* 533

SUMMARY 535
REVIEW QUESTIONS 536
KEY TERMS 537
COGLAB DEMONSTRATIONS 537
WEB RESOURCES 537

## CHAPTER 15

**Individual, Aging, and Gender Differences in Cognition 538**

Individual Differences in Cognition 539
- *Ability Differences* 539
- *Cognitive Styles* 545
- *Expert/Novice Differences* 548

The Effects of Aging on Cognition 549

Gender Differences in Cognition 551
- *Gender Differences in Skills and Abilities* 554
- *Gender Differences in Learning and Cognitive Styles* 565

SUMMARY 569
REVIEW QUESTIONS 571
KEY TERMS 571
COGLAB DEMONSTRATIONS 572
WEB RESOURCES 572

## CHAPTER 16

**Cognition in Cross-Cultural Perspective 573**

Examples of Studies of Cross-Cultural Cognition 579
- *Cross-Cultural Studies of Perception* 579
- *Cross-Cultural Studies of Memory* 586
- *Cross-Cultural Studies of Categorization* 590
- *Cross-Cultural Studies of Reasoning* 595
- *Cross-Cultural Studies of Counting* 598

Effects of Schooling and Literacy 602

Situated Cognition in Everyday Settings 609

SUMMARY 613
REVIEW QUESTIONS 614
KEY TERMS 615
COGLAB DEMONSTRATIONS 615
WEB RESOURCES 615

**Glossary 616**

**References 629**

**Author Index 660**

**Subject Index 671**

# Preface

Undergraduate students studying psychology have different reactions to the field of cognitive psychology. Some find it exciting and elegant, covering topics essential to understanding the human mind. Cognitive psychology, after all, raises questions about how the mind works—how we perceive people, events, and things; how and what we remember; how we mentally organize information; how we call on our mental information and resources to make important decisions. Other students find the field of cognitive psychology technical and "geeky"—filled with complicated models of phenomena far removed from everyday life. My goal in writing this book is to try to bridge that gap—to try to reach out to students who are in the latter camp to show them what this field offers to be excited about. I think much of the problem is due to the disconnection of laboratory phenomena from everyday life. Too often, cognition texts focus exclusively on the lab research, without showing students how that work bears on important, real-world issues of consequence. I hope when students finish this book, they see why cognitive psychologists are so passionate about their topic and their research.

## Pedagogical Philosophy: Encouraging Instructor Customization

A textbook author can choose either to be comprehensive and strive for encyclopedic coverage or to be selective and omit many worthwhile topics and studies. I hope I've struck a balance between these extremes but must confess I prefer the latter. This reflects my own teaching goals; I like to supplement textbook chapters with primary literature from journals. I have tried to keep chapters relatively short, in the hope instructors will supplement the text with other readings. My firm belief is that the best courses are those in which instructors are enthusiastic about the material; the relative brevity of the text is intended to encourage instructors to supplement and customize it with added coverage on topics they find especially interesting.

All important material is integrated into the text, rather than pulled out into boxes, asides, or extras that students might skip. This choice reflects my own experience as a student, as well as feedback from my students who say they find boxed material distracting and often treat it as optional.

## The Role of Context: What Shapes and Constrains Cognition

My goal is to encourage instructors and students alike to consider cognitive phenomena as having contexts that both foster and constrain their occurrence. Universals assumed or generalized from the laboratory do not always translate to every person in every situation. Too often, topics in cognitive psychology are presented as absolute, unchanging aspects of everyone's experience. Recent work in developmental psychology, cross-cultural psychology, and individual differences strongly suggests that this presentation is, at best, oversimplification and, at worst, fiction. I hope newer work in cognitive psychology can retain its rigor and elegance but can frame questions and issues more inclusively, reflecting a recognition of the ways in which people and situations differ as well as share similarities.

## Organization of This Book

This book is intended for a one-semester or one-term course for students who have already completed an introductory psychology course. It is organized into five parts. The first, containing the introductory chapter, locates the field historically, theoretically, and methodologically. In this chapter I introduce the major schools of thought that underlie the field of cognitive psychology and review the major methodological designs typically used by researchers in the field. A second chapter, newly added for this edition, reviews the major structures of the brain and major neuroscientific methods of study.

Part II is a review of topics that would generally be regarded as core aspects of cognition: perception, attention, and memory. The emphasis in these chapters is to review both the "classic" studies that define the field and the newer approaches that challenge long-standing assumptions. The focus of Part III is on knowledge representation and organization. These chapters center on questions of how we mentally represent and store the vast amounts of information we acquire throughout our lives. Part IV covers topics such as reasoning and decision making perhaps more extensively than in other books, probably due to my own research interests. In these chapters especially, I have tried to draw several connections between laboratory-based models and real-world problems.

Part V is the one that departs most from a "prototypical" cognitive psychology textbook. The last two chapters, on individual differences and cross-cultural approaches, include material not often covered in cognitive psychology courses. I feel strongly that these topics belong in a thorough examination of cognitive phenomena. Although traditional cognitive psychologists don't always consider these issues in their work, I believe they ought to and, in the future, will.

## New to This Edition

In response to feedback from students and faculty who have used this book, as well as other reviewers, several changes have been incorporated into the fourth edition. First, a new chapter—Chapter 2—has been added. It reviews major brain structures, as well as the topics of localization and lateralization of function, and includes an updated section (formerly a part of Chapter 1) on brain imaging techniques.

Chapter 3 introduces the perception of visual art, and discusses the missing letter effect in the context of research on word superiority. Chapter 4 includes a new section on inattentional blindness (integrated with the corresponding section on change blindness in Chapter 3). Chapter 4 introduces fMRI studies of remembered versus not-remembered material, and discusses new work on individual differences in working memory. Chapter 6 incorporates fMRI studies of false memories, recent work on flashbulb memories for 9/11, and research on false memories for pictures versus verbal material.

Chapter 7 clarifies information on how connectionist networks are trained, and expands the coverage of ACT models of memory. Chapter 8 clarifies the schema/concept distinction as well as the notion of an exemplar. Chapter 9 presents a new section on spatial cognition, including studies of people's knowledge of familiar spaces.

Chapter 10 presents a more complete listing of phonemes of English. Chapter 11 clarifies the concept of backtracking in problem solving. Chapter 12 incorporates recent work on "emotional" reasoning and the workings of the prefrontal cortex in reasoning. Chapter 13 includes a new example of recognition-primed decision making.

Throughout the book, new references and photographs are included. A special effort has been made to point the student to relevant work in cognitive neuroscience. A number of new figures have been added as well.

## Teaching Tools

References are made throughout the book to CogLab, Wadsworth's web-based program for presenting demonstrations and experiments in cognitive psychology. Instructors can arrange to buy access to this resource with the text. In addition, Key Terms in each chapter can be used as search terms in online databases such as PsycINFO, PsycFIRST, and InfoTrac College Edition®, available at many undergraduate institutions.

## Acknowledgments

The actual writing of the first edition of this book was a 5-year project. However, the groundwork for the book evolved over 15 years, stretching back to my own undergraduate and graduate education. I was fortunate to have benefited from the rigorous and dynamic teaching of Blythe Clinchy at Wellesley College and of Jonathan Baron, John Sabini, and Henry and Lila Gleitman at the University of Pennsylvania. My education and thinking about cognitive and developmental issues continued to profit from interactions with colleagues at Carleton College. Colleagues in Carleton's Cognitive Studies program—especially Roy Elveton, Susan Singer, and Matt Rand—as well as colleagues from other disciplines, including Deanna Haunsperger, Steven Kennedy, Marion Cass, Martha Paas, and others, have sharpened my pedagogical philosophy and helped me maintain a sense of humor and balance about the craziness that periodically invades Carleton.

One of the real joys of working at Carleton has been the privilege of teaching some incredibly talented, motivated, and energetic students. Students in my Cognitive Processes courses over the past 15 years have been kind enough to give me feedback on which chapters worked well and which ones didn't, and I thank them for their candor. Other current and former Carleton students helped me with the mundane but necessary tasks of checking references and writing for permissions, including Stephanie Aubry, Julie Greene, Simin Ho, Kitty Nolan, Scott Staupe, Jennifer Tourjé, Elizabeth White, and James Whitney for the first edition; Diane Mistele and Matt Maas for the second; April Anderson and Andy Hebrank for the third; and Allison Logeman for the fourth. Lori Dockery helped me track down answers to the trivia questions in Chapter 13. Kate Ainsworth allowed me to use the stimuli she created for a course project. My two secretaries, Ruby Hagberg and Marianne Elofson, and their student assistants—Karen Dawson, Ruby Eddie-Quartey, Lareina Ho, and Aimee Mayer—helped me prepare the first author index, Samantha Anders prepared this for the second edition, and Heather Wilde Geerts took on this task for the third edition with the assistance of students Jade Bender, Carey Tinkelenberg, and Julie Woulfe. For the fourth edition, the index was prepared with the very able assistance of Carey Tinkelenberg. Several current and former students posed for some of the photographs, including David Drebus, Loren Frank, Simin Ho, Beth Lavin, Amy Luckner, Nancy Michelsen, and Becky Reimer. Because my students have contributed so much to my thinking and professional development, it is special to me to be able to make them a tangible part of the book!

Carleton College has supported this project through three sabbaticals and two summer faculty development grants over the course of four editions. Dean Roy Elveton enthusiastically endorsed and funded this endeavor from the start. A dean can really make a difference in a faculty member's professional development, and Roy often went above and beyond the call of duty for me and several of my talented colleagues at Carleton during his brief administrative tenure. His belief in my ability to write this book is something I will always be grateful for. As a colleague in our Philosophy Department, Roy remains a most trusted mentor.

Much of the early work on the first edition of the book was completed during a sabbatical leave spent at the Claremont Graduate School and Pomona College. Colleagues there provided a stimulating and productive environment in which to write. For the second edition, Larry Wichlinski, a colleague in psychology at Carleton, educated me about neurological topics and brought to my attention a number of fascinating and intriguing findings. (And he never once complained about all the time I took up asking technical questions.) Clark Ohnesorge, was gracious enough to use my book in his teaching and to help me keep abreast of new developments in attentional research.

I owe a special debt to Vicki Knight, editor of the first and third editions. Her wise counsel, sharp sense of humor, love of animals, and excellent taste in restaurants have made this project one I've looked forward to working on. Her knowledge of psychology and its pedagogy never ceases to astound me. Vicki is a rare person: She cuts to the chase and speaks bluntly, while simultaneously inspiring loyalty and a deep desire to please her; almost every telephone conversation or e-mail note from her is a real day-brightener. I am extremely grateful to have had the chance to work so closely with such a gifted individual.

Thanks are also due Marianne Taflinger, senior editor for the second edition, who coordinated the reviewers and made a number of suggestions for improvement. For the first edition, Lauri Banks Ataide, Susan Haberkorn, Carline Haga, Diana Mara Henry, Laurie Jackson, Tessa A. McGlasson, and Katherine Minerva all displayed much graciousness and patience in working with a novice author. For the second through fourth editions, I've been extremely fortunate and wildly grateful to have Anne Draus at Scratchgravel Publishing Services handling the myriad details of copyediting, typesetting, design, and so on. She's a calm, competent, humorous professional who makes all the production tasks much less of a burden than they otherwise could be! Thanks are also due to Lillian Campobasso, Bob Western, Andrew Ogus, Vernon Boes, Kim Rokusek, Jennifer Mackres, Margaret Parks, and Alicia Barelli for their help with permissions, photographs, design, art coordination, and marketing for the second edition. For the third edition, I had an even better production team! Anne Draus at Scratchgravel and Paula Berman at Thomson deserve kudos and deep appreciation for the terrific group of folks they assembled. Linda Purrington was an eagle-eyed copy editor who kept me on my toes! Laura Molmud, photo editor, worked at lightning speed and was able to locate just the right photos to illustrate various concepts. Beth Zuber, permissions editor, was likewise always a few steps ahead of me, with a detail-oriented approach so necessary in this job. Vernon Boes was a real sport in getting the cover design just right. Lucy Faridnay, Dan Moneypenny, and Monica Sarmiento were cheerful despite all the work involved in coordinating reviews.

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Nancy Ashmore, publications director at St. Olaf College and a close friend, provided many of the photographs. She found ways of putting on film ideas that I could describe only imprecisely—and she did it all without ever losing her characteristic calm demeanor. Even when I asked her to come over to photograph "foods that begin with the letter *C*," she resisted the urge to flee. Thanks, Nancy!

Once again, Lori Van Wallendael from the University of North Carolina–Charlotte has done a fabulous job creating the Instructor's Manual with Test Bank.

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*Kathleen M. Galotti*

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# PART I

# Overview

1 Cognitive Psychology: History, Methods, and Paradigms
2 The Brain: An Overview of Structure and Function

CHAPTER

# 1

# Cognitive Psychology: History, Methods, and Paradigms

**Influences on the Study of Cognition**
- Structuralism
- Functionalism
- Behaviorism
- Gestalt Psychology
- Genetic Epistemology
- The Study of Individual Differences
- The “Cognitive Revolution”
- Current Trends in the Study of Cognition
- General Points

**Research Methods in Cognitive Psychology**
- Naturalistic Observation
- Introspection
- Controlled Observation and Clinical Interviews
- Experiments and Quasi-Experiments
- Investigations of Neural Underpinnings
- General Points

**Paradigms of Cognitive Psychology**
- The Information-Processing Approach
- The Connectionist Approach
- The Evolutionary Approach
- The Ecological Approach
- General Points

This book is about cognitive psychology—that branch of psychology concerned with how people acquire, store, transform, use, and communicate information (Neisser, 1967). Put differently, cognitive psychology deals with our mental life: what goes on inside our heads when we perceive, attend, remember, think, categorize, reason, decide, and so forth.

To get a better feel for the domain of cognitive psychology, let’s consider a few examples of cognitive activity.

> *You’re walking along a dark, unfamiliar city street. It’s raining and foggy, and you are cold and a bit apprehensive. As you walk past a small alley, you catch some movement out of the corner of your eye. You turn to look down the alley and start to make out a shape coming toward you. As the shape draws nearer, you are able to make out more and more features, and you suddenly realize that it’s . . .*

What cognitive processes are going on in this admittedly melodramatic example? In general, this example illustrates the initial acquisition and processing of information.

In particular, the cognitive processes depicted include **attention,** mentally focusing on some stimulus (the mysterious shape); **perception,** interpreting sensory information to yield meaningful information; and **pattern recognition,** classifying a stimulus into a known category. In recognizing the shape as something familiar, you no doubt called on **memory,** the storage facilities and retrieval processes of cognition. All this processing occurred rapidly, probably within a few seconds or less. Most of the cognitive processing in this example appears so effortless and automatic that we usually take it for granted.

Here's another example:

> *You're in a crowded public place, such as a shopping mall during the holiday season. Throngs of people push past you, and you're hot and tired. You head for a nearby bench, aiming to combine some rest with some people watching. As you make your way, a young woman about your age jostles up against you. You both offer polite apologies ("Oh, excuse me!" "Sorry!"), glancing at each other as you do. She immediately exclaims, "Oh, it's you! How are you? I never thought I'd run into anyone I know here—can you believe it?" You immediately paste a friendly but vague smile on your face to cover your frantic mental search: Who is this woman? She looks familiar, but why? Is she a former classmate? Did you and she attend camp together? Is she saying anything that you can use as a clue to place her?*

This example illustrates your use of memory processes, including **recognition** (you see the woman as familiar) and **recall** (you try to determine where you know her from). Other cognitive processes are involved here too, although they play a lesser role. For instance, you perceive the entity talking to you as a person, specifically a woman, more specifically a vaguely familiar woman. You pay **attention** to her. You may be using various strategies or techniques of **reasoning** and **problem solving** to try to figure out who she is. Your success or failure at this task may also depend on your mental organization of the knowledge you have accumulated in your lifetime—your **knowledge representation.** To communicate with her, you use **language** as well as nonverbal cues or signals. Eventually, you'll have to use **decision making** to determine how to deal with the situation: Will you admit your forgetfulness, or will you try to cover it up?

As these two examples demonstrate, our everyday lives involve a great deal of cognition. Furthermore, this everyday cognition is complex, often involving several cognitive processes. We tend to remain unaware of this complexity, however, because much of our cognitive processing occurs so often, so rapidly, and with so little effort that we may not even know it is taking place.

In both of the preceding examples, several cognitive processes were occurring either simultaneously or very closely in time. In fact, it is nearly impossible to specify, in either of these examples, exactly how many cognitive processes occurred or in what sequence. This uncertainty typifies everyday situations: So much is going on so quickly that we can't be sure of even what information is being received or used. How, then, can cognition be studied with any precision?

This kind of problem is one all scientists face: how to study a naturally occurring phenomenon with sufficient experimental rigor to draw firm conclusions. The answer, for many, is to try to isolate the phenomenon and bring it (or some stripped-down version of it) into the laboratory. The challenge, then, is to decide what is essential and what is inessential about the phenomenon under study.

For example, in studying how memory works, psychologists have often used experiments in which people are presented with lists of words or nonsense syllables. The experimenters then control or systematically vary variables such as the complexity, length, frequency, meaningfulness, relatedness, and rate of presentation of items on the list, along with the state of alertness, expertise, practice, and interest of the research participants. The experimenters assume factors that increase or decrease performance in the laboratory will also increase or decrease performance under less controlled conditions. Further, the researchers assume that although in everyday life people do not encounter material to be remembered in this manner, the processes of memory work in essentially the same ways in laboratory experiments as in everyday life. So if increasing the number of items to be remembered decreases memory performance in a laboratory, then we can also expect having to remember more information in an everyday situation would be more difficult than remembering less under the same circumstances.

The key challenge for all scientists, however, is to make sure the laboratory tasks they develop really do preserve the essential workings of the processes under study. The most rigorously controlled experiment is of at best limited value if the phenomenon being studied does not occur or occurs in significantly different ways outside the laboratory. Unfortunately, there is no simple or guaranteed way to ensure that laboratory tasks model everyday tasks. Therefore, students and other "consumers" of science must take a critical stance when considering how experimental situations apply to everyday ones. Throughout this book, we will be looking at how laboratory models do or don't accurately describe, explain, and predict cognitive processing in real life. We will also consider how situational and personal factors, such as people's level of development, personality variables, degree of expertise, gender, and cultural background, affect cognitive processing.

Before we discuss specific cognitive processes, however, an overview of the field of cognitive psychology will provide a useful framework within which to consider specific topics, experiments, and findings in the field. We will first examine the historical roots of cognitive psychology to see how the field has

Neighborhood Map
Manhattan Bus Map
Subway Map
Notices

Theodore Anderson/Getty Images

*An ordinary activity, such as reading a map, involves a great deal of cognitive processing.*

developed. Next, we'll look at traditional and common research methods used in cognitive psychology. Finally, we'll consider four paradigms, or schools of thought, that represent the current streams of thought in the field.

## ■ INFLUENCES ON THE STUDY OF COGNITION

A complete treatise on how modern cognitive psychology has evolved over the course of human history could fill several volumes and would obviously be beyond our scope. Worth noting, however, is that several ideas about certain mental abilities date back to at least the Greek philosophers Aristotle and Plato (Murray, 1988). For example, both these philosophers wrote extensively on the nature of memory. Plato, for instance, likened storing something in memory to writing on a wax tablet. In other writings, he compared the mind to an aviary in which many birds are flying, and memory retrieval to trying to catch a specific bird: Sometimes you can, but at other times you can grab only a nearby bird. Similarly, when I try to recall the name of the girl who sat behind me in third grade, I have trouble latching onto exactly the right one (was it Joan? Joanne? Anne?), but my choices are probably pretty close.

Other historians of psychology trace the field's roots to the philosophers of the 17th to 19th centuries, including John Locke, David Hume, John Stuart Mill, René Descartes, George Berkeley, and Immanuel Kant. These philosophers also debated the nature of mind and knowledge, with Locke, Hume, Berkeley, and Mill following Aristotle and a more empiricist position, and Descartes and Kant aligning with Plato and a nativist position.

Briefly, **empiricism** rests on the tenet that knowledge comes from an individual's own experience—that is, from the empirical information that people collect from their senses and experiences. Empiricists recognize individual differences in genetics but emphasize human nature's malleable, or changeable, aspects. Empiricists believe people are the way they are, and have the capabilities they have, largely because of previous learning. One mechanism by which such learning is thought to take place is through the mental **association** of two ideas. Locke (1690/1964) argued that two distinct ideas or experiences, having nothing to do with each other, could become joined in the mind simply because they happened to occur or to be presented to the individual at the same time. Empiricists accordingly believe the environment plays a powerful role in determining one's intellectual (and other) abilities.

**Nativism,** by contrast, emphasizes the role of constitutional factors—of native ability—over the role of learning in the acquisition of abilities and tendencies. Nativists attribute differences in individuals' abilities less to differences in learning than to differences in original, biologically endowed capacities and abilities. Nativism is an important idea in cognitive psychology, as we will see. Nativists often suggest that some cognitive functions come built in, as part of our legacy as human beings. "Hard-wired" functions such as short-term memory, for example, are attributed to innate structures of the human mind that are present in at least rudimentary form at birth and are not learned, formed, or created as a result of experience.

Interestingly, only in the last 120 years have central cognitive issues such as the nature of mind and the nature of information in the mind been seen as amenable to scientific psychological investigation. Indeed, until the 1870s no one really thought to ask whether actual data could help resolve any of these questions. When people began doing so, experimental psychology was born. However, the nativist–empiricist debate is still a controversial one in the 21st century (Pinker, 2002, p. 10). We will look next at different schools of experimental psychology that laid the foundations for cognitive psychology today.

## Structuralism

Many students are surprised to find out that psychology as a formal discipline has been around for little more than a century. Historians often date the "founding" of the actual field of psychology back to 1879, when Wilhelm Wundt converted a laboratory into the first institute for research in experimental psychology (Fancher, 1979). Wundt wanted to establish a "science of mind," to discover the laws and principles that explained our immediate conscious experience. In particular, Wundt wanted to identify the simplest essential units of the mind. In essence, he wanted to create a table of "mental elements," much like a chemist's periodic chart. Once the set of elements was identified, Wundt believed, psychologists could determine how these units combine to produce complex mental phenomena. Wundt foresaw an entire field devoted to the study of how systematically varying stimuli would affect or produce different mental states; he described this field in a volume titled *Principles of Physiological Psychology* (Fancher, 1979).

Wundt and his students carried out hundreds of studies, many involving a technique of investigation called **introspection.** Although this term today connotes "soul searching," Wundt's technique was much more focused. It consisted of presenting highly trained observers (usually graduate students) with various stimuli and asking them to describe their conscious experiences. Wundt assumed that the raw materials of consciousness were sensory and thus "below" the level of meaning. In particular, Wundt thought any conscious thought or idea resulted from a combination of sensations that could be defined in terms of exactly four properties: *mode* (for example, visual, auditory, tactile, olfactory), *quality* (such as color, shape, texture), *intensity,* and *duration.*

Wundt's goal was to "cut through the learned categories and concepts that define our everyday experience of the world" (Fancher, 1979, p. 140). Wundt believed strongly that with proper training, people could detect and report the workings of their own minds. A student of Wundt, Edward B. Titchener, applied the term **structuralism** to his own endeavors as well as to Wundt's (Hillner, 1984). The term was meant to convey Wundt's focus on what the elemental components of the mind are rather than on the question of *why* the mind works as it does.

The method of introspection, unfortunately, proved problematic, as we'll see shortly. Nonetheless, modern cognitive psychologists owe Wundt more than a historical debt. A pioneer in the study of many cognitive phenomena, he was the first to approach cognitive questions scientifically and the first to try to design experiments to test cognitive theories.

## Functionalism

While Wundt was working in Leipzig, an American named William James was working to establish the new discipline of psychology in the United States. In many ways, Wundt and James were opposites. A prolific researcher who personally carried out or supervised hundreds of rigorous experiments, Wundt was not known for his interpersonal style. James (the brother of the writer Henry James), in contrast, carried out little original research but wrote eloquently about psychological findings and their relevance to everyday life

(Fancher, 1979). His textbook *The Principles of Psychology* (1890/1983) is still highly regarded and widely cited today.

James regarded psychology's mission to be the explanation of our experience. Like Wundt, James was interested in conscious experience. Unlike Wundt, however, James was not interested in the elementary units of consciousness. Instead, he asked *why* the mind works the way it does. He assumed that the way the mind works has a great deal to do with its *function*—the purposes of its various operations. Hence the term **functionalism** was applied to his approach.

James's writings, which introduced psychological questions to American academics, still offer food for thought to students and teachers of psychology, perhaps because they so directly address everyday life. Consider one of the best-known chapters in his textbook, on "habit." James saw habit as the "flywheel of society" (1890/1983, Vol. 1, p. 125), a mechanism basic to keeping our behavior within bounds. He saw habits as inevitable and powerful and drew from this a practical conclusion:

> Every smallest stroke of virtue or of vice leaves its ever so little scar. The drunken Rip Van Winkle, in Jefferson's play, excuses himself for every fresh dereliction by saying, "I won't count this time!" Well! he may not count it, and a kind Heaven may not count it; but it is being counted none the less. Down among his nerve-cells and fibres the molecules are counting it, registering and storing it up to be used against him when the next temptation comes. (James, 1890/1983, Vol. 1, p. 131)

James's point, of course, is that people should take great care to avoid bad habits and establish good ones. He offered advice about how to do so, urging people to never allow an exception when trying to establish a good habit, to seize opportunities to act on resolutions, and to engage in a "little gratuitous effort" every day to keep the "faculty of effort" alive (James, 1890/1983, Vol. 1, p. 130).

Other American psychologists shared James's assumptions and approaches. Fellow functionalists such as John Dewey and Edward L. Thorndike, for example, shared James's conviction that the most important thing the mind did was to let the individual adapt to her or his environment.

Functionalists drew heavily on Darwinian evolutionary theory and tried to extend biological conceptions of adaptation to psychological phenomena (Hillner, 1984). Structuralists and functionalists differed in their methods as well as their focus. The structuralists were convinced the proper setting for experimental psychology was the laboratory, where experimental stimuli could be stripped of their everyday meanings to determine the true nature of mind. Functionalists disagreed sharply with this approach, attempting instead to study mental phenomena in real-life situations. Their basic belief was that psychologists should study whole organisms in whole, real-life tasks (Hillner, 1984).

## Behaviorism

You probably learned the terms *classical conditioning* and *instrumental conditioning* in your introductory psychology class. The Russian psychologist Ivan Pavlov used the first, and psychologists such as Edward Thorndike used the second, to explain psychological phenomena strictly in terms of observable stimuli and responses.

In the United States, a school of psychology known as **behaviorism** took root in the 1930s, dominating academic psychology until well into the 1960s. Many regard it as a branch of functionalism (Amsel, 1989). One of the general doctrines of behaviorism is that references to unobservable, subjective mental states (such as consciousness), as well as to unobservable, subjective processes (such as expecting, believing, understanding, remembering, hoping for, deciding, and perceiving), were to be banished from psychology proper, which behaviorists took to be the scientific study of behavior.

Behaviorists rejected such techniques of study as introspection, which they found in principle to be untestable. In an article published in 1913, John Watson most directly described his view of what psychology is and isn't:

> Psychology as the behaviorist views it is a purely objective natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no essential part of its methods, nor is the scientific value of its data dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness. The behaviorist, in his efforts to get a unitary scheme of animal response, recognizes no dividing line between man and brute. The behavior of man, with all of its refinement and complexity, forms only a part of the behaviorist's total scheme of investigation. (p. 158)

Why did behaviorists so disdain the technique of introspection? Mainly because of its obviously subjective nature and its inability to resolve disagreements about theory. Suppose two observers are presented with the same stimulus, and one reports an experience of "greenness" and the other an experience of "green-yellowness." Which one is correct? Is one misrepresenting or misinterpreting his or her experience? If no physiological cause (for example, color blindness) explains the different reports, then the scientist is left with an unresolvable dispute. Titchener restricted his research participants to graduate students trained to introspect "properly" (advising those who couldn't learn to do this to find another career). This, however, created more problems than it solved. The reasoning was circular: How do we know that a particular sensation is a true building block of cognition? Because trained observers report it to be so. How do we know the observers are trained? Because they consistently report that certain sensations and not others are the true elements of consciousness.

Watson, in fact, regarded all "mental" phenomena as reducible to behavioral and physiologic responses. Such things as "images" and "thoughts," he believed, resulted from low-level activity of the glands or small muscles. In his first textbook, Watson cited evidence showing that when people report they are "thinking," muscles in the tongue and larynx are actually moving slightly. Thought, for Watson, simply amounted to perception of these muscle movements (Fancher, 1979).

Watson's contribution to cognitive psychology—banishing all "mental language" from use—was largely negative, insofar as he believed the scientific study of mental phenomena was simply not possible. Watson and his followers did, however, encourage psychologists to think in terms of measures and research methods that moved beyond subjective introspection, thereby challenging later psychologists to develop more rigorous and more testable hypotheses and theories, as well as stricter research protocols.

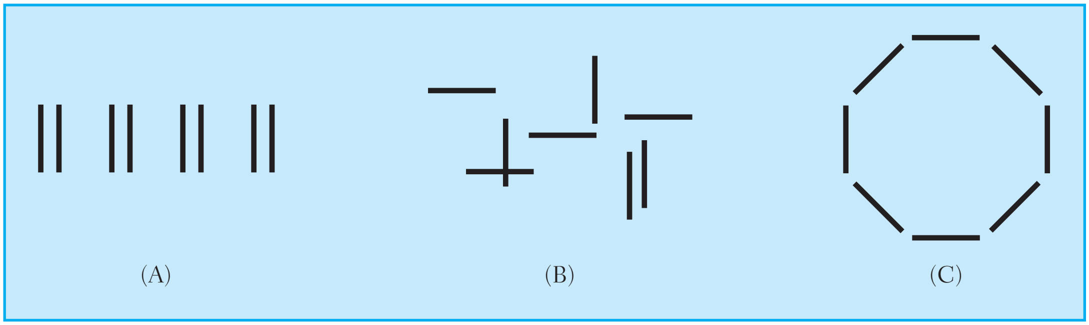
B. F. Skinner (1984), psychology's best-known behaviorist, took a different tack with regard to mental events and the issue of mental representations. Skinner argued that such "mentalistic" entities as images, sensations, and thoughts should *not* be excluded simply because they are difficult to study. Skinner believed in the existence of images, thoughts, and the like and agreed they were proper objects of study but objected to treating mental events and activities as fundamentally different from behavioral events and activities. In particular, he objected to hypothesizing the existence of **mental representations** (internal depictions of information), which he took to be internal copies of external stimuli. Skinner believed images and thoughts were likely to be no more or less than verbal labels for bodily processes. But even if mental events *were* real and separate entities, Skinner believed, they were triggered by external environmental stimuli and gave rise to behaviors. Therefore, he held, a simple functional analysis of the relationship between the stimuli and behaviors would avoid the well-known problems of studying mental events (Hergenhahn, 1986).

Other behaviorists were more accepting of the idea of mental representations. Edward Tolman, for example, believed even rats have some goals and expectations. As he explained it, a rat learning to run a maze must have the goal of attaining food and must acquire an internal representation—some cognitive map or other means of depicting information "in the head" about the maze—to locate the food at the maze's end. Tolman's work centered on demonstrating that animals had both expectations and internal representations that guided their behavior.

## Gestalt Psychology

The school of **Gestalt psychology** began in 1911 in Frankfurt, Germany, at a meeting of three psychologists: Max Wertheimer, Kurt Koffka, and Wolfgang Köhler (Murray, 1988). As the name *Gestalt* (a German word that loosely

**FIGURE 1-1** ■ *Examples of Gestalt figures. Although (A), (B), and (C) all contain eight equal lines, most people experience them differently, seeing (A) as four pairs of lines, (B) as eight unrelated lines, and (C) as a circle made up of eight line segments.*



translates to "configuration" or "shape") suggests, these psychologists' central assumption was that psychological phenomena could not be reduced to simple elements but rather had to be analyzed and studied in their entirety. Gestalt psychologists, who studied mainly perception and problem solving, believed an observer did not construct a coherent perception from simple, elementary sensory aspects of an experience but instead apprehended the total structure of an experience as a whole.

As a concrete example, consider Figure 1-1. Notice that (A), (B), and (C) contain the same elements—namely, eight equal line segments. However, most people experience the three arrays quite differently, seeing (A) as four pairs of line segments, (B) as eight line segments haphazardly arranged, and (C) as a circle, or more precisely, an octagon, made up of eight line segments. The arrangement of lines—that is, the relationships among the elements as a whole—plays an important role in determining our experience.

The Gestalt psychologists thus rejected structuralism, functionalism, and behaviorism as offering incomplete accounts of psychological and, in particular, cognitive experiences. They chose to study people's subjective experience of stimuli and to focus on how people use or impose structure and order on their experiences. They believed that the mind imposes its own structure and organization on stimuli and, in particular, organizes perceptions into *wholes* rather than discrete parts. These wholes tend to simplify stimuli. Thus, when we hear a melody, we experience not a collection of individual sounds but larger, more organized units: melodic lines.

## Genetic Epistemology

Jean Piaget, a Genevan scientist known as a naturalist, philosopher, logician, educator, and developmental psychologist (Flavell, 1963), conducted studies of the cognitive development of infants, children, and adolescents that have also helped to shape modern cognitive psychology. Piaget's work was largely sympathetic to the Gestalt idea that the relationship between parts and wholes is complex. Piaget sought to describe the intellectual structures underlying cognitive experience at different developmental points through an approach he called **genetic epistemology.** We'll discuss Piagetian theory in much more detail in Chapter 14; for now, only a brief overview will be given.

Piaget's observations of infants and children convinced him that a child's intellectual structures differ qualitatively from those of a mature adult. As he watched young children, for example, Piaget noticed that their assumptions about the numerosity of objects seemed to differ from those of an older child or adult. Specifically, young children seemed to believe that a row of, say, five buttons becomes more numerous if the row is simply spread out—an assumption a 6- or 7-year-old finds laughable.

> Char [aged 4 years, 4 months] also began by making a compact row of 11 buttons to equal the 6 spaced out buttons of the model, then as his row was longer than the other he removed 3 from the end, thus obtaining the same length: "Are they the same?—Yes.—Exactly?—Yes.—(The 6 elements of the model were then put further apart, and the 8 in his copy were put closer together.) And now?—There are more there (the 6)." (Piaget, 1965, p. 75)

In this example, Char seems to be confusing the *length* of the row with the *numerosity* of the row. In other words, a typical child of this age regards the number of buttons as being the same thing as the length of the row they are in. More generally, Piaget believed that most children of this age—in what he called the preoperational stage of development—confuse the way things look with the way things really are. We'll see more details about this topic in Chapter 14.

Piaget believed that children in different stages of cognitive development used different mental structures to perceive, remember, and think about the world. In fact, the mental structures available at any given point of development limited and constrained the cognitive abilities of a child, making them cognitively different from those of an older child in a different stage, or of an adult.

## The Study of Individual Differences

Yet another strand of the history of psychology is important to mention here, even though no particular "school" is associated with it: the investigations into **individual differences** in human cognitive abilities by Sir Francis Galton and his followers. Galton, a half-cousin of Charles Darwin, inherited a substantial sum in his early 20s that afforded him the time and resources to pursue his interests. A child prodigy himself (he read and wrote by the age of 2½), Galton trained in medicine and mathematics at Cambridge University, England. Like many of his fellow students (and many of today's college students), Galton felt a great deal of academic pressure and competitiveness and "was constantly preoccupied with his standing relative to his fellow students" (Fancher, 1979, p. 257). This strong preoccupation (which may have contributed to a breakdown he suffered at Cambridge) developed into a lifelong interest in measuring intellectual ability.

Galton's interest in intellectual differences among people stemmed in part from his reading of his cousin Charles Darwin's writings on evolution. Darwin believed animals (including humans) evolved through a process he called natural selection, by which certain inherited traits are perpetuated because individuals possessing those traits are more likely to survive and reproduce. Galton wondered whether intellectual talents could also be inherited. Galton noticed "intelligence" or "smartness" or "eminence" seemed to run in families; that is, smart parents appeared to produce smart children. Of course, this could be explained in terms of either genetics or environment (for example, intelligent parents may have greater resources to spend on their children's education and/or greater interest or motivation to do so). Thus Galton's question of how large a role genetics plays in intelligence was difficult to answer. To address it, Galton put his mathematical training to use in analyzing data (usually family trees of "eminent" men) and, later, inventing statistical tests, some of which are still used today.

Galton (1883/1907) studied a variety of cognitive abilities, in each case focusing on ways of measuring the ability and then noting its variation among different individuals. Among the abilities he studied (in both laboratory and "naturalistic" settings) was mental imagery. He developed a questionnaire, instructing respondents to "think of some definite object—suppose it is your breakfast-table as you sat down this morning—and consider carefully the picture that rises before your mind's eye" (p. 58). He then asked, Is the image dim or clear? Are all of the objects in the image well defined? Does part of the image seem to be better defined? Are the colors of the objects in the image distinct and natural? Galton was surprised to discover much variability in this capacity: Some respondents reported almost no imagery; others experienced images so vividly they could hardly tell they *were* images!

Galton left a large legacy to psychology, and to cognitive psychology in particular. His invention of tests and questionnaires to assess mental abilities inspired later cognitive psychologists to develop similar measures. His statistical analyses, later refined by other statisticians, allowed hypotheses to be rigorously tested. His work on mental imagery is still cited by current investigators. Most broadly, Galton's work challenged psychologists, both those who believed in the importance of genetic influences and those strongly opposed to the idea, to think about the nature of mental—that is, cognitive—abilities and capacities.

## The "Cognitive Revolution"

Despite the early attempts to define and study mental life, psychology, especially American psychology, came to embrace the behaviorist tradition in the first five decades of the 1900s. A number of historical trends, both within and outside academia, came together in the years during and following World War II to produce what many psychologists think of as a "revolution" in the field of cognitive psychology. This **cognitive revolution,** a new series of psychological investigations, was mainly a rejection of the behaviorist assumption that mental events and states were beyond the realm of scientific study or that mental representations did not exist. In particular, the "revolutionaries" came to believe no complete explanation of a person's functioning could exist that did not refer to the person's mental representations of the world. This directly challenged the fundamental tenet of radical behaviorism, that concepts such as "mental representation" were not needed to explain behavior.

One of the first of these historical trends was a product of the war itself: the establishment of the field of **human factors engineering.** During the war, military personnel had to be trained to operate complicated pieces of equipment. Engineers quickly found they needed to design equipment (such as instrument operating panels, radar screens, and communication devices) to suit the capacities of the people operating it. Lachman, Lachman, and Butterfield (1979) offered an anecdote about why such problems were important to solve:

> One type of plane often crashed while landing. It turned out that the lever that the pilot had to use for braking was near the lever that retracted the landing gear. During landing, the pilot could not take his eyes off the runway: He had to work by touch alone. Sometimes pilots retracted their landing gear instead of putting on their brakes; they touched the ground with the belly of the plane at top speed. The best way to keep them from crashing was not to exhort them to be careful; they were already highly motivated to avoid crashing and getting killed. Improving training procedures was also an inefficient approach; pilots with many safe landings behind them committed this error as well as rookie pilots.
>
> The most reasonable approach was to redesign the craft's controls so that completely different arm movements were required for braking and for retracting the landing gear. (p. 57)

Psychologists and engineers thus developed the concept of the man–machine system, now more accurately referred to as the **person–machine system:** the idea that machinery operated by a person must be designed to interact with the operator's physical, cognitive, and motivational capacities and limitations.

Psychologists in World War II also borrowed concepts, terminology, and analogies from communications engineering. Engineers concerned with the design of such things as telephones and telegraph systems talked about the exchange of information through various "channels" (such as telegraph wires and telephone lines). Different kinds of channels differ in how much information they can transmit per unit of time and how accurately.

Psychologists learning of this work started to describe human beings as "communication channels," examining their capacities for receiving, sending, and processing information and the circumstances under which they distort the information they receive. Humans were quickly seen to share properties with better known, inanimate communications channels and came to be described as **limited-capacity processors** of information.

What is a limited-capacity processor? As the name suggests, it means that people can do only so many things at once. When I'm typing, I find it difficult (actually, impossible) to simultaneously keep up my end of a conversation or read an editorial or follow a television news broadcast. Similarly, when I concentrate on balancing my checkbook, I can't also recite multiplication tables or remember all the teachers I've had from kindergarten on. Although I can do some tasks at the same time (I can fold the laundry while I watch television), the number and kinds of things I can do at the same time are limited. Many landmark studies of cognitive psychology—those that cognitive psychologists regard as "classics"—date from just after World War II and clearly focus on exploring the nature of our capacity limitations.

For instance, George Miller, in his 1956 paper "The Magical Number Seven, Plus or Minus Two," observed that (a) the number of unrelated things we can perceive distinctly without counting, (b) the number of unrelated things on a list we can immediately remember, and (c) the number of stimuli we can make absolute discriminations among is for most normal adults between five and nine. Miller's work thus exemplified how the limits of people's cognitive capacities could be measured and tested.

At about the same time, developments in the field of **linguistics,** the study of language, made clear that people routinely process enormously complex information. Work by linguist Noam Chomsky revolutionized the field of linguistics, and both linguists and psychologists began to see the central importance of studying how people acquire, understand, and produce language.

In addition, Chomsky's early work (1957, 1959, 1965) showed that behaviorism could not adequately explain language. Consider the question of how language is acquired. A behaviorist might explain language acquisition as a result of parents' reinforcing a child's grammatical utterances and punishing (or at least not reinforcing) ungrammatical utterances. However, both linguists and psychologists soon realized such an account had to be wrong. For one thing, psychologists and linguists who observed young children with their parents found that parents typically respond to the *content* rather than to the *form* of the child's language utterances (Brown & Hanlon, 1970). For another, even when parents (or teachers) explicitly tried to correct children's grammar, they could not. Children seemed simply not to "hear" the problems, as is evident in the following dialogue (McNeill, 1966, p. 69):

CHILD: Nobody don't like me.
MOTHER: No, say, "Nobody likes me." [eight repetitions of this dialogue]
MOTHER: No, now listen carefully; say, "Nobody likes me."
CHILD: Oh! Nobody don't likes me.

(Clearly, this mother was more focused on the child's linguistic than emotional development!)

Chomsky's work thus posed a fundamental challenge to psychologists: Here were human beings, already shown to be limited-capacity processors, quickly acquiring what seemed an enormously complicated body of knowledge—language—and using it easily. How could this be?

Reversing engineers' arguments that machines must be designed to fit people's capabilities, many linguists tried to describe structures complex enough to process language. Chomsky (1957, 1965) argued that underlying people's language abilities is an implicit system of rules, collectively known as a *generative grammar.* These rules allow speakers to construct, and listeners to understand, sentences that are "legal" in the language. For example, "Did you eat all the oat bran cereal?" is a legal, well-formed sentence, but "Bran the did all oat eat you cereal?" is not. Our generative grammar, a mentally represented system of rules, tells us so, because it can produce (generate) the first sentence but not the second.

Chomsky (1957, 1965) did not believe all the rules of a language are consciously accessible to speakers of that language. Instead, he believed the rules operate implicitly: We don't necessarily know exactly what all the rules are, but we use them rather easily to produce understandable sentences and to avoid producing gobbledygook.

Another strand of the cognitive revolution came from developments in neuroscience, the study of the brain-based underpinnings of psychological and behavioral functions. A major debate in the neuroscience community had been going on for centuries, all the way back to Descartes, over the issue of **localization of function.** To say a function is "localized" in a particular region is, roughly, to claim that the neural structures supporting that function reside in a specific brain area. In a major work published in 1929, a very influential neuroscientist, Karl Lashley, had claimed there was no reason to believe that major functions (such as language and memory) are localized (Gardner, 1985).

However, research in the late 1940s and 1950s accumulated to challenge that view. Work by Donald Hebb suggested that some kinds of functions, such as visual perceptions, were constructed over time by the building of *cell* *assemblies*—connections among sets of cells in the brain. In the 1950s and 1960s, Nobel Prize–winning neurophysiologists David Hubel and Torsten Wiesel discovered that specific cells in the visual cortex of cats were in fact specialized to respond to specific kinds of stimuli (orientation of lines, particular shapes). Equally important, Hubel and Weisel demonstrated the importance of early experience in nervous system development. Kittens who were experimentally restricted to an environment with only horizontal lines would fail to develop the ability to perceive vertical lines. This work suggested that at least some functions are localized in the brain (Gardner, 1985).

There is yet one more thread to the cognitive revolution, also dating from about World War II: the development of computers and artificially intelligent systems. In 1936, a mathematician named Alan Turing wrote a paper describing universal machines: mathematical entities that were simple in nature but capable in principle of solving logical or mathematical problems. This paper ultimately led to what some psychologists and computer scientists call the **computer metaphor:** the comparison of people's cognitive activities to an operating computer. Just as computers have to be fed data, people have to acquire information.

Both computers and people often store information and must therefore have structures and processes that allow such storage. People and computers often need to recode information—that is, to change the way it is recorded or presented. People and computers must also manipulate information in other ways—transform it, for example, by rearranging it, adding to or subtracting from it, deducing from it, and so on. Computer scientists working on the problem of **artificial intelligence** now study how to program computers to solve the same kinds of problems humans can and whether computers can use the same methods that people apparently use to solve such problems.

## Current Trends in the Study of Cognition

During the 1970s, researchers in different fields started to notice they were investigating common questions: the nature of mind and of cognition; how information is acquired, processed, stored, and transmitted; and how knowledge is represented. Scholars from fields such as cognitive psychology, computer science, philosophy, linguistics, neuroscience, and anthropology, recognizing their mutual interests, came together to found an interdisciplinary field known as **cognitive science.** Gardner (1985) even gave this field a birth date—September 11, 1956—when several founders of the field attended a symposium on information theory at the Massachusetts Institute of Technology (MIT).

Gardner (1985) pointed out that the field of cognitive science rests on certain common assumptions. Most important among these is the assumption that cognition must be analyzed at what is called the *level of representation*.

This means cognitive scientists agree that cognitive theories incorporate such constructs as symbols, rules, images, or ideas—in Gardner's words, "the stuff . . . found between input and output" (p. 38). Thus cognitive scientists focus on representations of information rather than on how nerve cells in the brain work or on historical or cultural influences.

Another approach to studying cognitive issues comes from clinical work. Practitioners of **cognitive neuropsychology** (Ellis & Young, 1988) study cognitive deficits in certain brain-damaged individuals. Ellis and Young described P.H., a 19-year-old who lost his right arm in a motorcycle accident and sustained a severe head injury that left him in a coma for almost two weeks. Four years after his accident, P.H. appeared to have normal language abilities, including reading, and he tested normal in many short- and long-term memory tests. His IQ (91) also seemed normal. His head injury seemed to have caused at least one cognitive deficit, however:

> One of P.H.'s problems was most resistant to rehabilitation; he could not recognize people's faces. As soon as a familiar person spoke he would know who it was but, to P.H., all faces seemed unfamiliar. He could tell if a face belonged to a man or a woman, an old or a young person, and he could describe the general appearance and facial features reasonably accurately. But P.H. had no sense of recognizing people who had previously been very familiar to him. In neuropsychological terms, his accident had left P.H. prosopagnosic—able to see, but unable to recognize once familiar faces. (Ellis & Young, 1988, pp. 1–2)

Cognitive neuropsychologists proceed by identifying people with certain patterns of brain damage and examining their cognitive performance. What cognitive processes can these individuals no longer perform? What cognitive activities have been spared? By finding answers to such questions, cognitive neuropsychologists not only might help certain people but might better understand how everyone's cognitive processes operate. In later chapters of the book, we'll be returning to examples from cognitive neuropsychology.

## General Points

Each school of psychology described so far has left a visible legacy to modern cognitive psychology. Structuralism asked the question, What are the elementary units and processes of the mind? Functionalists reminded psychologists to focus on the larger purposes and contexts that cognitive processes serve. Behaviorists challenged psychologists to develop testable hypotheses and to avoid unresolvable debates. The Gestalt psychologists pointed out that an understanding of individual units would not automatically lead to an understanding of whole processes and systems. Piaget reminded cognitive psychologists to consider how cognition develops and evolves, and Galton demonstrated that individuals can differ in their cognitive processing. Developments in engineering, computer science, linguistics, and neuroscience have uncovered processes by which information can be efficiently represented, stored, and transformed, providing analogies and metaphors for cognitive psychologists to use in constructing and testing models of cognition. As we take up particular topics, we will see more of how cognitive psychology's different roots have shaped the field.

Keep in mind that cognitive psychology shares in the discoveries made in other fields, just as other fields share in the discoveries made by cognitive psychology. This sharing and borrowing of research methods, terminology, and analyses gives many investigators a sense of common purpose. It also all but requires cognitive psychologists to keep abreast of new developments in fields related to cognition.

## ■ RESEARCH METHODS IN COGNITIVE PSYCHOLOGY

Throughout this book, we will be reviewing different empirical studies of cognition. Before we plunge into those studies, however, we will look at some of the different kinds of studies that cognitive psychologists conduct. The following descriptions do not exhaust all the studies a cognitive psychologist *could* conduct but should acquaint you with the major methodological approaches to cognitive psychology.

### Naturalistic Observation

As the name suggests, **naturalistic observation** consists of an observer watching people in familiar, everyday contexts going about their cognitive business. For example, an investigator might watch as people try to figure out how to work a new automated teller machine (ATM) at an airport. Ideally, the observer remains as unobtrusive as possible, so as to disrupt or alter the behaviors being observed as little as possible. In this example, for instance, the investigator might stand nearby and surreptitiously note what people who use the ATM do and say. Being unobtrusive is much harder than it might sound. The observer needs to make sure the people being observed are comfortable and do not feel as though they are "under a microscope." At the same time, the observer wants to avoid causing the people being observed to "perform" for the observer. In any case, the observer can hardly fully assess his or her own effects on the observation: After all, how can one know what people would have done had they not been observed?

Observational studies have the advantage that the things studied really do occur in the real world and not just in an experimental laboratory. Psychologists call this property **ecological validity.** Furthermore, the observer has a chance to see just how cognitive processes work in natural settings: how flexible they are, how they are affected by environmental changes, how rich and complex actual behavior is. Naturalistic observation is relatively easy to do, doesn't typically require a lot of resources to carry out, and does not require other people to formally volunteer for study.

The disadvantage of naturalistic observation is a lack of **experimental control.** The observer has no means of isolating the causes of different behaviors or reactions. All he can do is collect observations and try to infer relationships among them. However plausible different hypotheses may seem, the observer has no way of verifying them. Some psychologists believe that naturalistic observation is most appropriately used to identify problems, issues, or phenomena of interest to be investigated with other research methods.

A second problem, which all scientists face, is that an observer's recordings are only as good as her initial plan for what is important to record. The settings and people she chooses to observe, the behaviors and reactions she chooses to record, the manner of recording, and the duration and frequency of observation all influence the results and conclusions she can later draw. Moreover, whatever biases the observer brings to the study (and, as we will see in Chapter 13, all of us are subject to a large number of biases) limit and possibly distort the recordings made.

## Introspection

We have already seen one special kind of observation, dating back to the laboratory of Wilhelm Wundt. In the technique of introspection, the observer observes his or her own mental processes. For example, participants might be asked to solve complicated arithmetic problems without paper or pencil and to "think aloud" as they do so.

Introspection has all the benefits and drawbacks of other observational studies, plus a few more. One additional benefit is that observing one's own reactions and behavior may give one better insight into an experience and the factors that influenced it, yielding a richer, more complete picture than an outsider could observe. But observing yourself is a double-edged sword. Although perhaps a better observer in some ways than an outsider, you may also be more biased in regard to your own cognition. People observing their own mental processes may be more concerned with their level of performance and may be motivated to subtly and unconsciously distort their observations. They may try to make their mental processes appear more organized, logical, thorough, and so forth, than they actually are. They may be unwilling to admit when their cognitive processes seem flawed or random. Moreover, with some cognitive tasks (especially demanding ones), observers may have few resources left with which to observe and record.

## Controlled Observation and Clinical Interviews

As the term **controlled observation** suggests, this method gives researchers a little more influence over the setting in which observations are conducted. Investigators using this research method try to standardize the setting for all participants, in many cases manipulating specific conditions to see how participants will be affected. In the ATM machine example, for instance, the investigator might arrange for the ATM machine to display different instructions to different people. The study would still be observational (because the researcher would not control who used the machine or when), but the researcher would be trying to channel the behavior in certain ways.

In **clinical interviews,** the investigator tries to channel the process even more. The investigator begins by asking each participant a series of open-ended questions. In the introspection example cited earlier, for instance, the interviewer might again ask the participant to think about the problem and describe his approaches to it. With the clinical interview method, however, instead of allowing the participant to respond freely, the interviewer follows up with another set of questions. Depending on the participant's responses, the interviewer may pursue one or another of many possible lines of questioning, trying to follow each participant's own thinking and experience while focusing on specific issues or questions.

## Experiments and Quasi-Experiments

The major distinction between experiments and observational methods is the investigator's degree of experimental control. Having experimental control means the experimenter can assign participants to different experimental conditions so as to minimize preexisting differences between them. Ideally, the experimenter can control all variables that might affect the performance of research participants *other than* the variables on which the study is focusing. A true **experiment** is one in which the experimenter manipulates one or more independent variables (the experimental conditions) and observes how the recorded measures (dependent variables) change as a result.

For example, an experiment in cognitive psychology might proceed as follows: An experimenter recruits a number of people for a study of memory, randomly assigns them to one of two groups, and presents each group with exactly the same stimuli, using exactly the same procedures and settings and varying only the instructions (the independent variable) for the two groups of participants. The experimenter then observes the overall performance of the participants on a later memory test (the dependent variable).

This example illustrates a **between-subjects design,** wherein different experimental participants are assigned to different experimental conditions and the researcher looks for differences in performance between the two groups. In contrast, a **within-subjects design** exposes the same experimental participants to more than one condition. For example, participants might perform several memory tasks but receive a different set of instructions for each task. The investigator then compares the performance of the participants in the first condition to the performance of the *same* participants in another condition.

Some independent variables preclude random assignment (that is, having the experimenter assign a research participant to a particular condition in an experiment). For example, experimenters cannot reassign participants to a different gender, ethnicity, age, or educational background. Studies that appear in other ways to be experiments but that have one or more of these factors as independent variables (or fail to become true experiments in other ways) are called **quasi-experiments** (Campbell & Stanley, 1963).

Scientists value experiments and quasi-experiments because they enable researchers to isolate causal factors and make better supported claims about causality than is possible using observational methods alone. However, many experiments fail to fully capture real-world phenomena in the experimental task or research design. The laboratory setting or the artificiality or formality of the task may prevent research participants from behaving normally, for example. Further, the kinds of tasks amenable to experimental study may not be those most important or most common in everyday life. As a result, experimenters risk studying phenomena that relate only weakly to people's real-world experience.

The general point to draw here is that the various research methods are all ways of investigating questions. Ultimately, cognitive psychologists hope that the findings from different studies will converge on similar explanations.

## Investigations of Neural Underpinnings

Much work in cognitive neuropsychology involves examining people's brains. Before the second half of the 20th century, this kind of examination could be conducted only after a patient died, during an autopsy. However, since the 1970s various techniques of **brain imaging,** the construction of pictures of the anatomy and functioning of intact brains, have been developed. We will discuss many of these techniques in Chapter 2.

## General Points

This brief outline of different research designs barely scratches the surface of all the important things we could look at. There are a few general points to note, however. First, cognitive psychologists use a variety of approaches to study cognitive phenomena. In part, these approaches reflect philosophic differences among psychologists over what is important to study and how tradeoffs should be made between certain drawbacks and benefits. In part, they reflect the intellectual framework in which researchers find themselves working. They may also reflect how amenable different areas of cognition are to different research approaches.

Second, no research design is perfect. Each has certain potential benefits and limitations that researchers must weigh in designing studies. Students, professors, and other researchers must also examine the design of studies, both critically and appreciatively, thinking carefully about how well the research design answers the research question posed. I hope you'll keep these thoughts in mind as you read in the rest of the book examples of the wide variety of research studies that cognitive psychologists have carried out.

Table 1-1 presents a summary (oversimplified) of the different traditions within cognitive psychology and/or cognitive neuropsychology. For each tradition, it lists one of the major researchers associated with the tradition, the central question posed by the tradition, and the research methods typically used.

**Table 1-1** Antecedents of Cognitive Psychology

| *Tradition* | *Name* | *Question* | *Method* |
|---|---|---|---|
| Individual differences | Galton | How do people differ? | Tests, statistical analysis |
| Physiology | Broca | What kinds of disruptions accompany specific kinds of brain damage? | Tests, observations, autopsy |
| Structuralism | Titchener | What are the basic building blocks of consciousness? | Introspection under controlled conditions |
| Genetic epistemology | Piaget | How do mental structures develop? | Observation, interview |
| Functionalism | James | Why does the mind have the operations it has? | Introspection under naturalistic conditions |
| Gestalt psychology | Koffka | What organization does the mind impose on different configurations of simple stimuli? | Introspection under controlled conditions |
| Behaviorism | Skinner | How is behavior affected by context? | Observation under controlled conditions |
| Human factors engineering | Broadbent | What leads to maximally efficient use of a machine by a person? | Observation under controlled conditions |

SOURCE: Komatsu (1995).

## ■ PARADIGMS OF COGNITIVE PSYCHOLOGY

Having looked at cognitive psychology's historical roots and research methods, we can now focus on cognitive psychology today. In this section, we will examine the four major paradigms that cognitive psychologists use in planning and executing their research.

First of all, what is a **paradigm?** The word has several related meanings, but you can think of it as a body of knowledge structured according to what its proponents consider important and what they do not. Paradigms include the assumptions investigators make in studying a phenomenon. Paradigms also specify what kinds of experimental methods and measures are appropriate for an investigation. Paradigms are thus intellectual frameworks that guide investigators in studying and understanding phenomena.

In this section, we'll review four paradigms used by cognitive psychologists today. In learning about each one, ask yourself the following questions: What assumptions underlie the paradigm? What questions or issues does the paradigm emphasize? What analogies (such as the analogy between the computer and the mind) does the paradigm use? What research methods and measures does the paradigm favor?

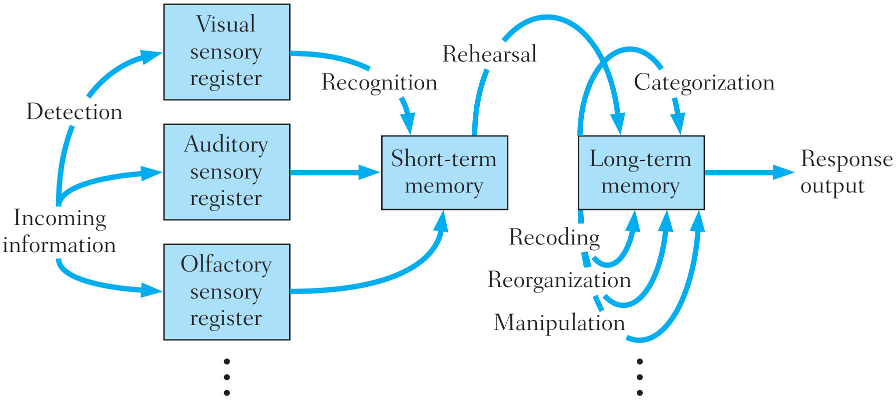
### The Information-Processing Approach

The **information-processing approach** dominated cognitive psychology in the 1960s and 1970s and remains strong and influential today (Atkinson & Shiffrin, 1968). As its name implies, the information-processing approach draws an analogy between human cognition and computerized processing of information. Central to the information-processing approach is the idea that cognition can be thought of as information (what we see, hear, read about, think about) passing through a system (us or, more specifically, our minds).

Researchers following an information-processing approach often assume that information is processed (received, stored, recoded, transformed, retrieved, and transmitted) in stages and that it is stored in specific places while being processed. One goal within this framework, then, is to determine what these stages and storage places are and how they work.

Other assumptions underlie the information-processing approach as well. One is that people's cognitive abilities can be thought of as "systems" of interrelated capacities. We know different individuals have different cognitive capacities—different attention spans, memory capacities, and language skills, to name a few. Information-processing theorists try to find the relationships between these capacities, to explain how individuals go about performing specific cognitive tasks.

**FIGURE 1-2** ■ *A typical information-processing model.*


Visual sensory register
Auditory sensory register
Olfactory sensory register
Detection
Incoming information
Recognition
Rehearsal
Short-term memory
Categorization
Long-term memory
Response output
Recoding
Reorganization
Manipulation

In accordance with the computer metaphor, information-processing theorists assume that people, like computers, are general-purpose symbol manipulators. In other words, people, like computers, can perform astonishing cognitive feats by applying only a few mental operations to symbols (such as letters, numbers, propositions, or scenes). Information is then stored symbolically, and the way it is coded and stored greatly affects how easy it is to use it later (as when we want to recall information or manipulate it in some way).

A general-purpose information-processing system is shown in Figure 1-2. Note the various memory stores where information is held for possible later use and the different processes that operate on the information at different points or that transfer it from store to store. Certain processes, such as detection and recognition, are used at the beginning of information processing; others, such as recoding or retrieval, have to do with memory storage; still others, such as reasoning or concept formation, have to do with putting information together in new ways. In this model, boxes represent stores, and arrows represent processes (leading some to refer to information-processing models as “boxes-and-arrows” models of cognition). Altogether, the model is depicted best by something computer scientists call *flowcharts*, which illustrate the sequential flow of information through a system.

The information-processing tradition is rooted in structuralism, in that its followers attempt to identify the basic capacities and processes we use in cognition. The computer metaphor used in this approach also shows an indebtedness to the fields of engineering and communications. Psychologists working in the information-processing tradition are interested in relating individual and developmental differences to differences in basic capacities and processes. Typically, information-processing psychologists use experimental and quasi-experimental techniques in their investigations.

## The Connectionist Approach

Early in the 1980s, researchers from a variety of disciplines began to explore alternatives to the information-processing approach that could explain cognition. The framework they established is known as **connectionism** (sometimes also called *parallel-distributed processing,* or *PDP*). Its name is derived from models depicting cognition as a network of connections among simple (and usually numerous) processing units (McClelland, 1988). Because these units are sometimes compared to *neurons,* the cells that transmit electrical impulses and underlie all sensation and muscle movement, connectionist models are sometimes called **neural networks** (technically speaking, there are distinctions between connectionist and neural network models, but we will not review them here).

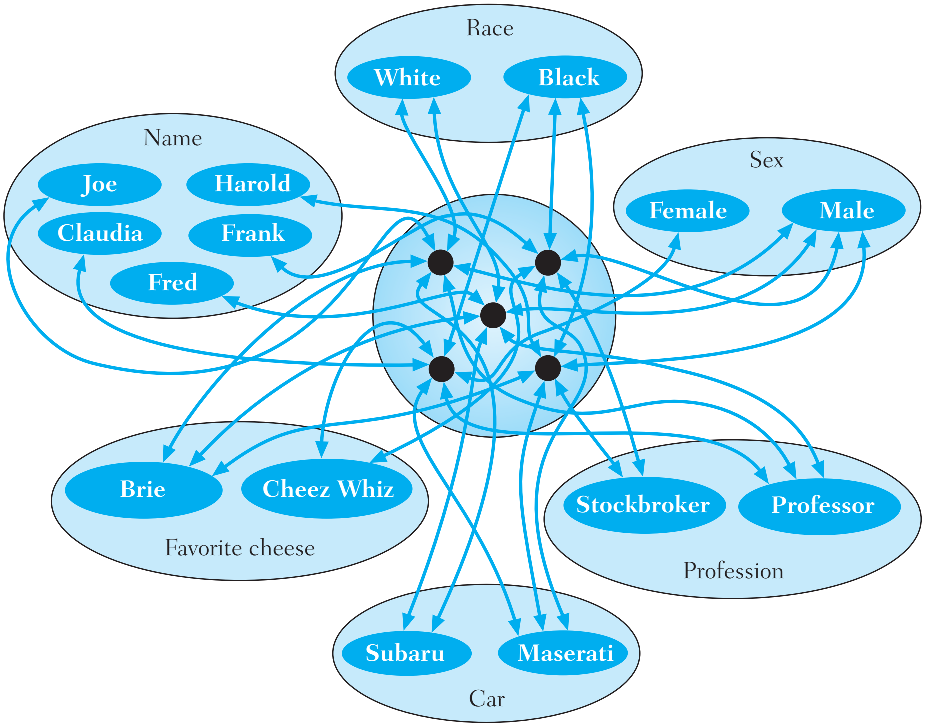
Each unit is connected to other units in a large network. Each unit has some level of activation at any particular moment in time. The exact level of activation depends on the input to that unit from both the environment and other units to which it is connected. Connections between two units have weights, which can be positive or negative. A positively weighted connection causes one unit to excite, or raise the level of activation of units to which it is connected; a negatively weighted connection has the opposite effect, inhibiting or lowering the activation of connected units.

Figure 1-3 depicts a connectionist network, showing both units and their connections. In this example, the units are the black circles at the center of the figure, with all the arrows pointing to them. Each of these units (sometimes called *nodes*) represents a particular individual. Each unit is connected to other units (shown as small ellipses) that depict certain information about individuals—for example, their names, cars, or professions. The arrows between units depict excitatory, or positively weighted, connections. When any unit reaches a certain level of activation, it activates all the other units to which it has positively weighted connections. In this example, all units within the same larger ellipse have negatively weighted, or inhibitory, connections. Thus, if the node for "Joe" is activated, it inhibits activation of the nodes "Claudia," "Fred," "Frank," and "Harold." At the same time, the "Joe" node activates the top left-hand node in the center circle, and activates the nodes "male," "professor," "Subaru," and "brie." The activation of these nodes inhibits, or lowers, the activation of all other nodes in their respective ellipses.

One major difference between the information-processing and the connectionist approaches is the manner in which cognitive processes are assumed to occur. In information-processing models, cognition is typically assumed to occur *serially*—that is, in discrete stages (first one process occurs, feeding information into the next process, which feeds information into the next process, and so on). In contrast, most (but not all) connectionist models assume that cognitive processes occur in *parallel,* many at the same time.

**FIGURE 1-3** ■ *A typical connectionist model.*

**SOURCE:** Martindale (1991, p. 15).


Race
White
Black
Name
Joe
Harold
Claudia
Frank
Fred
Sex
Female
Male
Brie
Cheez Whiz
Favorite cheese
Stockbroker
Professor
Profession
Subaru
Maserati
Car

The connectionist framework allows for a wide variety of models that can vary in the number of units hypothesized, number and pattern of connections among units, and connection of units to the environment. All connectionist models share the assumption, however, that there is no need to hypothesize a central processor that directs the flow of information from one process or storage area to another. Instead, different patterns of activation account for the various cognitive processes (Dawson, 1998). Knowledge is not stored in various storehouses but within connections between units. Learning occurs when new connective patterns are established that change the weights of connections between units.

Feldman and Ballard (1982), in an early description of connectionism, argued that this approach is more consistent with the way the brain functions than an information-processing approach. The brain, they argued, is made up of many neurons connected to one another in various complex ways. The authors asserted that “the fundamental premise of connectionism is that individual neurons *do not transmit large amounts of symbolic information.* Instead they compute by being *appropriately connected* to large numbers of similar units. This is in sharp contrast to the conventional computer model of intelligence prevalent in computer science and cognitive psychology" (p. 208). Rumelhart (1989, p. 134) puts the issue more simply: "Connectionism seeks to replace the computer metaphor of the information-processing framework with a brain metaphor."

Like the information-processing approach, connectionism draws from structuralism an interest in the elements of cognitive functioning. However, whereas information processors look to computer science, connectionists look to cognitive neuropsychology and cognitive neuroscience for information to help them construct their theories and models. Information-processing accounts of cognition try to provide explanations at a more abstract, symbolic level than do connectionist accounts. Connectionist models are more concerned with the "subsymbolic" level: how cognitive processes actually could be carried out by a brain. Connectionism, being much newer than information processing, is just beginning to map out explanations for individual and developmental differences. Most connectionist work seeks to replicate the findings of experimental and quasi-experimental research using computer programs based on a neural network model.

## The Evolutionary Approach

Some of our most remarkable cognitive abilities and achievements are ones we typically take for granted. Two that come immediately to mind are the ability to perceive three-dimensional objects correctly and the ability to understand and produce language. These abilities may seem rather trivial and mundane—after all, a 3-year-old can do quite a bit of both. However, researchers in the field of artificial intelligence quickly found that it is not so easy to program computers to carry out even rudimentary versions of these tasks (Winston, 1992).

So why can young children do these tasks? How can a wide range of people carry them out seemingly with little effort, even people who don't seem particularly gifted intellectually? Some psychologists search for an answer in evolutionary theory (Cosmides & Tooby, 2002; Richerson & Boyd, 2000). The argument goes something like this: Like other animal minds, the human mind is a biological system, one that has evolved over generations. Like other animal minds, it too is subject to the laws of natural selection. Therefore, the human mind has responded to evolutionary pressures to adapt in certain ways rather than others in response to the environments encountered by our predecessors. Evolutionary psychologist Leda Cosmides (1989) notes that the environments our ancestors experienced were not simply physical, but ecological and social as well.

The idea here is that humans have specialized areas of competence produced by our evolutionary heritage. Cosmides and Tooby (2002) argue that people have "a large and heterogeneous set of evolved, reliably developing, dedicated problem-solving programs, each of which is specialized to solve a particular domain or class of adaptive problems (e.g., grammar acquisition, mate acquisition, food aversion, way finding)." In other words, people have special-purpose mechanisms (including cognitive mechanisms) specific to a certain context or class of problems.

Cosmides and Tooby (2000, 2002) believe that some of the most significant issues our ancestors faced involved social issues, such as creating and enforcing social contracts. To do this, people must be especially good at reasoning about costs and benefits, and be able to detect cheating in a social exchange. Therefore, evolutionary psychologists predict that people's reasoning will be especially enhanced when they are reasoning about cheating, a topic we examine in much greater detail in Chapter 12.

In general, evolutionary psychologists believe we understand a system best if we understand the evolutionary pressures on our ancestors. Explaining how a system of reasoning works, they believe, is much easier if we understand how evolutionary forces shaped the system in certain directions rather than other, equally plausible ones.

## The Ecological Approach

A fourth major approach to the study of cognition comes from both psychologists and anthropologists, and overlaps much more with the evolutionary approach than it does with either the information-processing or connectionist approach. The central tenet of this approach is that cognition does not occur in isolation from larger cultural contexts; all cognitive activities are shaped by the culture and by the context in which they occur.

Jean Lave, a current theorist in this tradition, has conducted some fascinating work that illustrates the **ecological approach.** Lave (1988) described the results of the Adult Math Project as "an observational and experimental investigation of everyday arithmetic practices" (p. 1). Lave, Murtaugh, and de la Rocha (1984) studied how people used arithmetic in their everyday lives. In one study, they followed people on grocery-shopping trips to analyze how and when people calculate "best buys." They found that people's methods of calculation varied with the context. This was somewhat surprising, because students in our culture are taught to use the same specified formulas on all problems of a given type to yield one definite numerical answer. To illustrate, compare a typical third-grade arithmetic problem presented by teachers to students—"Brandi had eight seashells. Nikki had five more. How many seashells did the two of them have together?"—with the following problem, posed and solved by one of the grocery shoppers, regarding the number of apples she should purchase for her family for the week:

> There's only about three or four [apples] at home, and I have four kids, so you figure at least two apiece in the next three days. These are the kinds of things I have to resupply. I only have a certain amount of storage space in the refrigerator, so I can't load it up totally. . . . Now that I'm home in the summertime, this is a good snack food. And I like an apple sometimes at lunchtime when I come home. (Murtaugh, 1985, p. 188)

Lave (1988) pointed out a number of contrasts between this arithmetic problem solving and the kind used in solving school problems. First, the second example has many possible answers (for example, 5, 6, 9), unlike the first problem, which has one (13). Second, the first problem is given to the problem solver to solve; the second is constructed by the problem solver herself. Third, the first problem is somewhat disconnected from personal experience, goals, and interests, whereas the second comes out of practical daily living.

Although there has been much recent interest in the ecological approach, the idea of studying cognition in everyday contexts actually arose

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HARD TOOTH
THRIFTY

Nancy J. Ashmore

*Research following the ecological approach examines the cognitive processing of people in everyday situations.*

several years earlier. A major proponent of this viewpoint was J. J. Gibson, whose work on perception we will discuss at length in Chapter 3. Ulric Neisser, a friend and colleague of Gibson, wrote a book in 1976 aimed at redirecting the field of psychology toward studying more "realistic" cognitive phenomena.

We can see the influences of both the functionalist and the Gestalt schools on the ecological approach. The functionalists focused on the purposes served by cognitive processes, certainly an ecological question. Gestalt psychology's emphasis on the context surrounding any experience is likewise compatible with the ecological approach. The ecological approach would deny the usefulness (and perhaps even the possibility) of studying cognitive phenomena in artificial circumstances divorced from larger contexts. Thus this tradition relies less on laboratory experiments or computer simulations and more on naturalistic observation and field studies to explore cognition.

## General Points

Each of these four paradigms makes an important contribution to cognitive psychology, and in some ways the four offer complementary perspectives on how the underlying principles of cognition ought to be investigated and understood. The information-processing paradigm, for example, focuses researchers on the functional aspects of cognition—what kinds of processes are used toward what ends. The connectionist approach, in contrast, focuses on the underlying "hardware"—how the global cognitive processes described by an information-processing model are implemented in the human brain. The evolutionary approach centers on questions of how a cognitive system or function has evolved over generations. The ecological approach stresses the need to consider the context of any cognitive process to understand more completely how that process functions in the real world.

Not all cognitive research fits neatly into one of these three paradigms. Some research incorporates parts of different paradigms; some fits no paradigm neatly. However, I hope these four paradigms will provide a useful backdrop against which to consider individual studies.

This framework offers a sense of where we're headed in the rest of the book, as we take up specific cognitive topics in more detail. Throughout, you should examine how the research studies discussed bear on cognitive activities in your everyday life. Are the questions posed, and the research approaches used to answer them, appropriate? How do the theoretical assumptions shape the way the questions are posed? What do the research findings mean, and what new questions do they raise?

Cognitive psychology is my field. Not surprisingly, I've found it full of fascinating, deeply rooted questions, complex as well as elegant, and relevant to many real-world issues. I hope, after reading this book, that you too will find this field an important one, a field worth knowing about.

## SUMMARY

1. Cognition plays a large role in our everyday existence. We take much of our cognitive experience for granted because the ways in which we function cognitively are so routine we simply don't pay attention to them. Nonetheless, on closer inspection we see that many cognitive activities are astonishingly complex.
2. We've examined different traditions in the study of cognition, tracing the history of study back at least as far as Wundt's Leipzig laboratory. We've seen how different major schools of thought—structuralism, functionalism, behaviorism, and Gestalt approaches—have framed cognitive questions.
3. Structuralism, a school of psychology associated with Wilhelm Wundt, sought to discover the laws and principles that explain our immediate conscious experience. In particular, structuralists wanted to identify the simplest essential units of the mind and to determine how these units combine to produce complex mental phenomena.
4. Functionalism, a school of psychology associated with William James, took as the basic aim of psychology understanding the function of the mind—the ways in which mental functions let individuals adapt to their environment.
5. Behaviorism, regarded by some as a branch of functionalism, took as the central aim of psychology the scientific study of behavior, an observable consequence of psychological experience. Radical behaviorists insisted that references to unobservable, subjective, mental states (such as consciousness) as well as to unobservable, subjective processes (such as expecting, believing, understanding, remembering, hoping for, deciding, perceiving) should be banished from psychology proper.
6. The school of Gestalt psychology held as its central assumption that psychological phenomena cannot be reduced to simple elements but must be analyzed and studied in their entirety. Gestalt psychologists believed observers do not construct a coherent perception from simple, elementary sensory aspects of an experience but instead apprehend the total structure of an experience as a whole.
7. Work by Jean Piaget illustrated the fact that cognitive processes change in predictable ways as children develop. Francis Galton emphasized the idea that individuals differ, even as adults, in their cognitive capacities, abilities, and preferences.
8. We've also seen how the present study of cognitive psychology grows out of, and contributes to, innovations in other fields, such as computer science, communications, engineering, linguistics, evolution, and anthropology.

9. Cognitive psychology draws upon many different research methods, including experiments, quasi-experiments, controlled observation, and naturalistic observation.
10. Finally, we've reviewed four major approaches to the modern study of cognitive phenomena: the information-processing, connectionist, evolutionary, and ecological paradigms. We've seen that the information-processing approach emphasizes stagelike processing of information and specific storage of that information during processing. The connectionist approach instead depicts cognitive processing as a pattern of excitation and inhibition in a network of connections among simple (and usually numerous) processing units that operate in parallel. The evolutionary paradigm examines how a cognitive process has been shaped by environmental pressure over long periods of time. The ecological paradigm stresses the ways in which the environment and the context shape the way cognitive processing occurs.

## Review Questions

1. What roles do laboratory experiments and naturalistic observation play in cognitive research?
2. What similarities and differences exist among the following three "schools" of psychology: structuralism, functionalism, behaviorism?
3. What is a mental representation, and how is this concept viewed by Gestalt psychologists, information-processing psychologists, behaviorist psychologists, and connectionists?
4. Describe how research on cognitive development and individual differences might bear on cognitive psychology.
5. What was the "cognitive revolution"? What resulted from it?
6. Describe and critique the major research methods of cognitive psychology.
7. Compare and contrast the four major paradigms of cognitive psychology reviewed in this chapter (information processing, connectionism, the evolutionary approach, the ecological approach).

## Key Terms

artificial intelligence
association
attention
behaviorism
between-subjects design
brain imaging
clinical interview
cognitive neuropsychology
cognitive revolution
cognitive science
computer metaphor
connectionism
controlled observation
decision making
ecological approach

ecological validity
empiricism
experiment
experimental control
functionalism
genetic epistemology
Gestalt psychology
human factors engineering
individual differences
information-processing approach
introspection
knowledge representation
language
limited-capacity processor
linguistics
localization of function
memory
mental representation
nativism
naturalistic observation
neural network
paradigm
pattern recognition
perception
person–machine system
problem solving
quasi-experiment
reasoning
recall
recognition
structuralism
within-subjects design

## CogLab Demonstrations

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

## Web Resources

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

CHAPTER

2

# The Brain: An Overview of Structure and Function

**Structure of the Brain**
    The Hindbrain and Midbrain
    The Forebrain

**Localization of Function**

**Lateralization of Function**

**Brain Imaging Techniques**

When the field of cognitive psychology first began (in the 1950s and ’60s), cognitive psychologists found the workings of the brain to be quite interesting, but not necessarily relevant to their understanding of how cognitive processes worked. The idea was that description of cognitive processes and structures was best done at a level of abstraction above the neural level, which was thought to be too inordinately complicated. Many feared that a description of how each neuron in the brain worked would not yield a comprehensible explanation of, say, how your learning of French verb endings takes place. The level of detail of the neurons in your brain would simply not provide a very useful explanation, whereas one couched in terms of theoretical ideas such as memory storage areas (which might not physically exist) would. Theorists began to distinguish between different “levels” of explanation—a symbolic and abstract one for cognition, as opposed to a neural level for the actual functioning of cognitive processes in real time.

There is still strong argument among psychologists, biologists, philosophers, and computer scientists over which level of explanation is most useful for different kinds of understanding. However, increasing numbers of cognitive psychologists have become interested in the functioning of the brain as an underpinning for cognitive activity. Although the question of which level provides the most useful explanation remains, many cognitive psychologists feel they cannot investigate cognition without a working knowledge of how the brain develops and functions.

Of course, the topic of brain functioning and its relationship to cognition is itself a vast and complex one, and only brief highlights are given here. The interested student is referred to other, in-depth treatments of the topic (e.g., Gazzaniga, 2004; Johnson, Munakata, & Gilmore, 2002). First, some growth statistics: The brain grows from 0 to 350 grams (about three-quarters of a pound) during the prenatal period, but this growth doesn't stop at birth. The maximum brain weight of 1350 grams (about three pounds) is achieved when the individual is about 20 years old (Nowakowski & Hayes, 2002). Most post-birth growth takes place before the child's fourth birthday, but some changes continue through adulthood.

## ■ STRUCTURE OF THE BRAIN

There are obviously a lot of different structures to talk about when we talk about the brain. We'll need to talk first about different divisions of the brain, and we'll begin with a phylogenetic division. Figure 2-1 shows various structures of the adult brain, including the hindbrain, midbrain, and forebrain. In our brief discussion, we will focus specifically on the cerebral cortex, a part of the forebrain. However, it is worth talking briefly about the hindbrain and midbrain first.

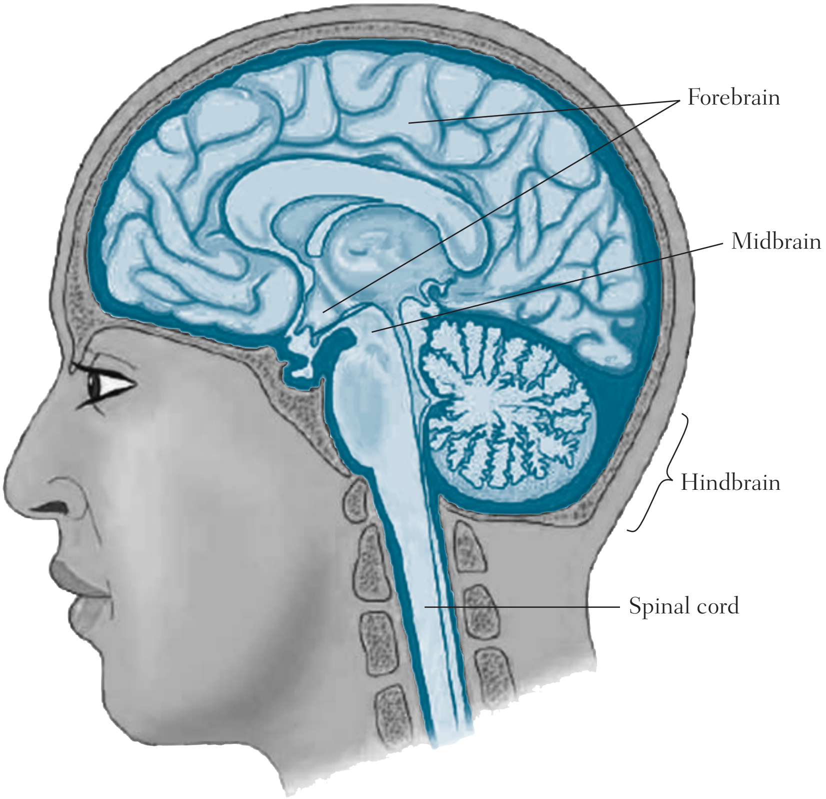
### The Hindbrain and Midbrain

The **hindbrain** develops originally as one of three bulges in the embryo's neural tube. Evolutionarily, structures within the hindbrain are the most primitive (Zillmer & Spiers, 2001). The brain stem (a structure consisting of the medulla and pons in the hindbrain, as well as the midbrain and certain structures of the forebrain), shown in Figure 2-2, comprises about 4.4% of the total weight of an adult brain; the cerebellum accounts for an additional 10.5%.

The hindbrain contain three major structures. The **medulla oblongata** (sometimes referred to simply as the medulla) transmits information from the spinal cord to the brain and regulates life support functions such as respiration, blood pressure, coughing, sneezing, vomiting, and heart rate (Pritchard &

**FIGURE 2-1** ■ *Major structures in the brain.*

**SOURCE:** Wilson (2003, p. 95).



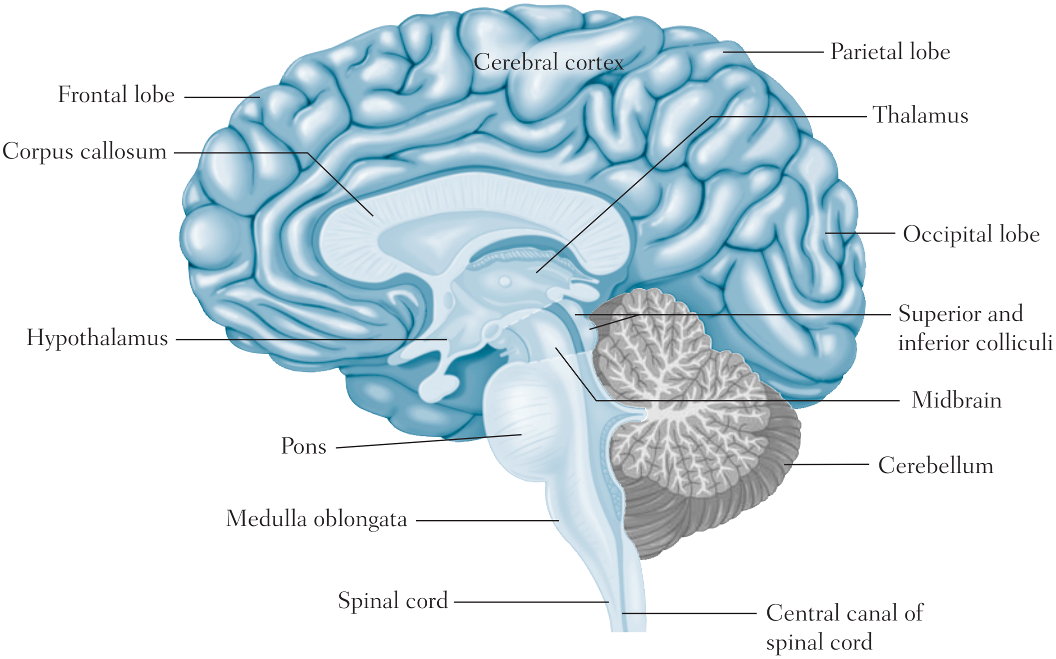
Alloway, 1999). The **pons** (the name derives from the Latin word for bridge) also acts as a neural relay center, facilitating the "crossover" of information between the left side of the body and the right side of the brain and vice versa. It is also involved in balance and in the processing of both visual and auditory information.

The **cerebellum** contains neurons that coordinate muscular activity (Pritchard & Alloway, 1999). It is one of the most primitive brain structures. It also governs balance and is involved in general motor behavior and coordination. Brain lesions in the cerebellum can cause irregular and jerky movements, tremors, and impairment of balance and of gait. It has also been implicated in people's ability to shift attention between visual and auditory stimuli, and in dealing with temporal stimuli such as rhythm (Akshoomoff & Courchesne, 1994).

The **midbrain** is located (unsurprisingly) in the middle of the brain. Many of the structures contained in the midbrain (such as the inferior and superior

**FIGURE 2-2** ■ *The human brain in midline and brain stem.*

**SOURCE:** Kalat (1998, p. 87).


Cerebral cortex
Parietal lobe
Frontal lobe
Thalamus
Corpus callosum
Occipital lobe
Superior and inferior colliculi
Hypothalamus
Midbrain
Pons
Cerebellum
Medulla oblongata
Spinal cord
Central canal of spinal cord

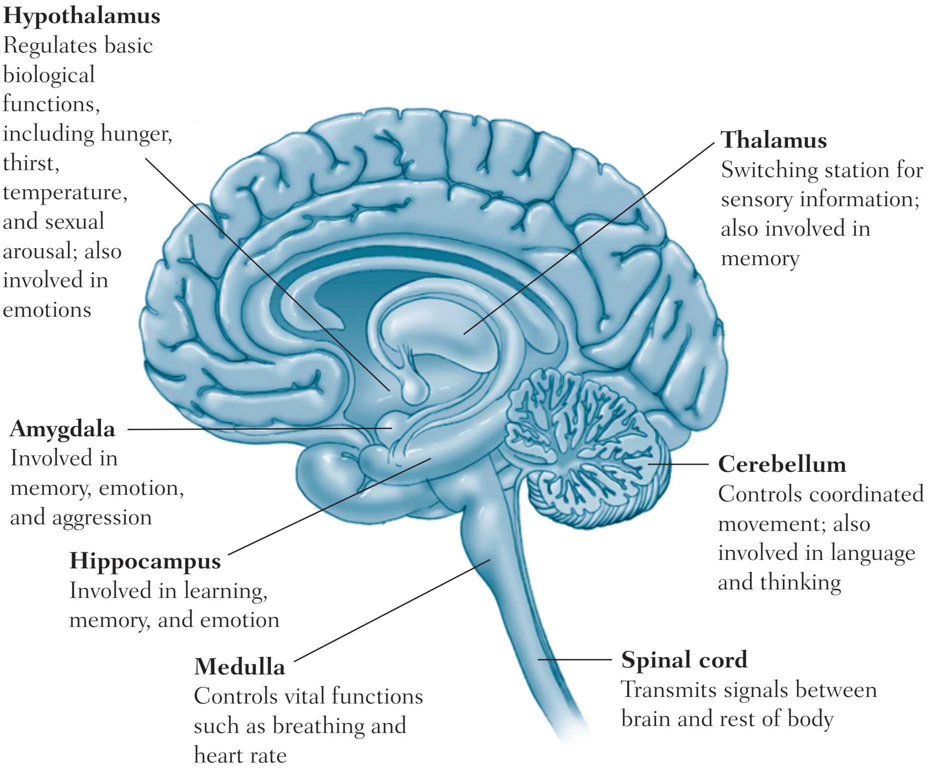
colliculi) are involved in relaying information between other brain regions, such as the cerebellum and forebrain. Another midbrain structure, the reticular formation, helps keep us awake and alert and is involved in the sudden arousal we may need to respond to a threatening or attention-grabbing stimulus (Pritchard & Alloway, 1999).

## The Forebrain

Because of our interest in cognitive issues, we will focus the remainder of our discussion of the brain on the **forebrain.** Some of the structures of the forebrain are presented in Figure 2-3. The **thalamus,** for example, is yet another structure for relaying information, especially to the cerebral cortex (Pritchard & Alloway, 1999), which we will talk about shortly. The **hypothalamus** controls the pituitary gland by releasing hormones, specialized chemicals that help to regulate other glands in the body. The hypothalamus also controls so-called homeostatic behaviors, such as eating, drinking, temperature control, sleeping, sexual behaviors, and emotional reactions. Other structures, such as the **hippocampus,** involved in the formation of long-term memories, and the

**FIGURE 2-3** ■ *Subcortical structures of the brain.*

**SOURCE:** Goldstein (1994, p. 89).


**Hypothalamus**
Regulates basic biological functions, including hunger, thirst, temperature, and sexual arousal; also involved in emotions
**Thalamus**
Switching station for sensory information; also involved in memory
**Amygdala**
Involved in memory, emotion, and aggression
**Cerebellum**
Controls coordinated movement; also involved in language and thinking
**Hippocampus**
Involved in learning, memory, and emotion
**Spinal cord**
Transmits signals between brain and rest of body
**Medulla**
Controls vital functions such as breathing and heart rate

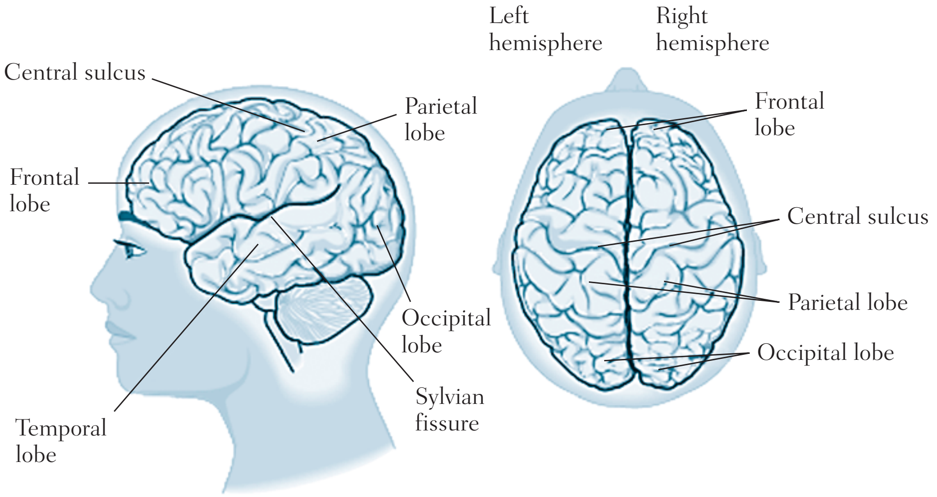
**amygdala,** which modulates the strength of emotional memories and is involved in emotional learning, are also located in the forebrain, as are the basal ganglia, which are involved in the production of motor behavior.

We will discuss many of these structures, including the hippocampus and amygdala, in the chapters to come. For the present, we will focus on the cerebrum (from the Latin word for brain), the largest structure in the brain. It consists of a layer called the **cerebral cortex,** consisting of about a half-dozen layers of neurons with white matter beneath, that carries information between the cortex and the thalamus or between different parts of the cortex.

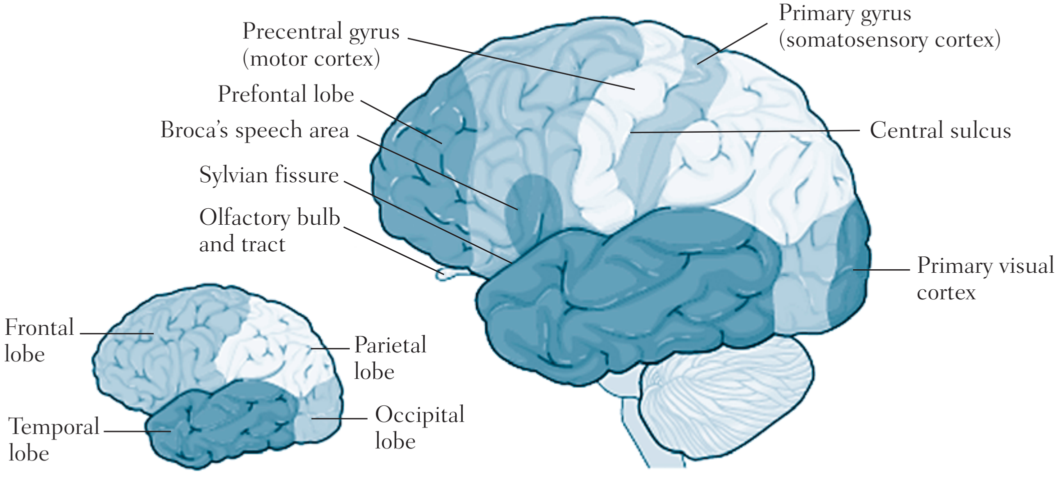
Figure 2-4 presents a more detailed diagram of the cerebral cortex, which neurologists divide into four lobes: **frontal** (underneath the forehead), **parietal** (underneath the top rear part of the skull), **occipital** (at the back of the head), and **temporal** (on the side of the head) (Pritchard & Alloway, 1999). The left and right hemispheres are connected by either the corpus callosum (in the case of the frontal, parietal, and occiptal lobes) or the anterior commisure

**FIGURE 2-4** ■ *The cerebrum in two views: in the skull and removed from the skull.*

**SOURCE:** Wilson (2003, p. 101).


Central sulcus
Parietal lobe
Frontal lobe
Occipital lobe
Sylvian fissure
Temporal lobe
Left hemisphere
Right hemisphere
Frontal lobe
Central sulcus
Parietal lobe
Occipital lobe

**Anatomical areas (left lateral view)** **Anatomical areas (top view)**


Precentral gyrus (motor cortex)
Prefontal lobe
Broca's speech area
Sylvian fissure
Olfactory bulb and tract
Primary gyrus (somatosensory cortex)
Central sulcus
Primary visual cortex
Frontal lobe
Temporal lobe
Parietal lobe
Occipital lobe

**Anatomical areas (left lateral view)**

(in the case of the temporal lobes). A structure known as the central sulcus (a prominent shallow groove on the surface of the brain) divides the frontal and parietal lobes; another sulcus, the lateral sulcus, helps define the temporal lobe. Actually, since our heads have two sides, right and left, we have two lobes of each kind—the right frontal, left frontal, right parietal, left parietal, and so forth (Pritchard & Alloway, 1999).

The parietal lobes contain the somatosensory cortex, which is contained in the postcentral gyrus (a gyrus is a convolution or ridge of the brain), the area just behind the central sulcus. It is involved in the processing of sensory information from the body—for example, sensations of pain, pressure, touch, or temperature (Pritchard & Alloway, 1999). The occipital lobes process visual information, and the temporal lobes auditory information, as well the ability to recognize certain stimuli such as faces. Because the temporal lobes are right above structures such as the amygdala and hippocampus, both involved in memory, damage to the temporal lobes can result in memory disruption as well.

The frontal lobes have three separate regions. The **motor cortex** (located in the precentral gyrus) directs fine motor movement; the premotor cortex seems to be involved in planning such movements. The **prefrontal cortex** or lobe is involved with what neuroscientists call **executive functioning**—planning, making decisions, implementing strategies, inhibiting inappropriate behaviors, and using working memory to process information. Damage to certain parts of the prefrontal cortex can also result in marked changes in personality, mood, affect, and the ability to control inappropriate behavior (Pritchard & Alloway, 1999).

The prefrontal cortex shows the longest period of maturation; it appears to be one of the last brain regions to mature (Casey, Giedd, & Thomas, 2000). Interestingly, this region may also be one of the "first to go" in aging effects seen toward the end of life. It has been hypothesized that brain regions that show the most plasticity over the longest periods may be the most sensitive to environmental toxins or stressors.

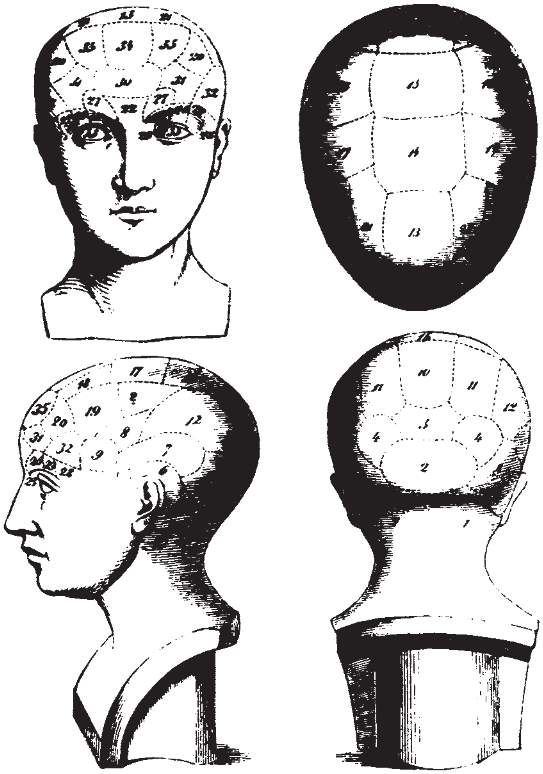
## ■ LOCALIZATION OF FUNCTION

When I describe a particular brain region or structure as having a particular role to play (as in memory or attention), you may wonder what the basis of such a claim is. That is, how do neuroscientists *know* what brain region does what? The answer lies in studies of **localization of function,** a means of mapping the brain.

The original idea of localization of function traces back to an Austrian anatomist named Franz Gall (1758–1828), who proposed an early localization theory. Gall believed in something called **faculty psychology,** a term that has nothing to do with why your college instructors are or are not crazy! Faculty psychology was the theory that different mental abilities, such as reading or computation, were independent and autonomous functions, carried out in different parts of the brain (Fodor, 1983). Gall believed that different locations in the brain were associated with such faculties as parental love, combativeness, acquisitiveness, and secretiveness, to name a few. Later, Gall's

**FIGURE 2-5** ■ *Phrenology head. Specific locations on the skull were thought to correspond to specific abilities.*

**SOURCE:** Zillmer & Spiers (2001, p. 16).



student Johan Spurzheim carried on Gall's teachings, developing the study of **phrenology** (see Figure 2-5), a now discredited idea that psychological strengths and weaknesses could be precisely correlated to the relative sizes of different brain areas.

The major problem with phrenology was not the assumption that different parts of the brain controlled different functions, but rather with two subsidiary assumptions: (1) that the size of a portion of the brain corresponded to its relative power and (2) that different faculties were absolutely independent. We now know that different mental activities—for example, perception and attention—are not wholly distinct and independent, but rather interact in many different ways. We also know that the overall size of a brain or brain area is not indicative of the functioning of that area. Therefore, having a different configuration of bumps and indentations in a brain does not determine or even predict how an individual will function cognitively or socially.

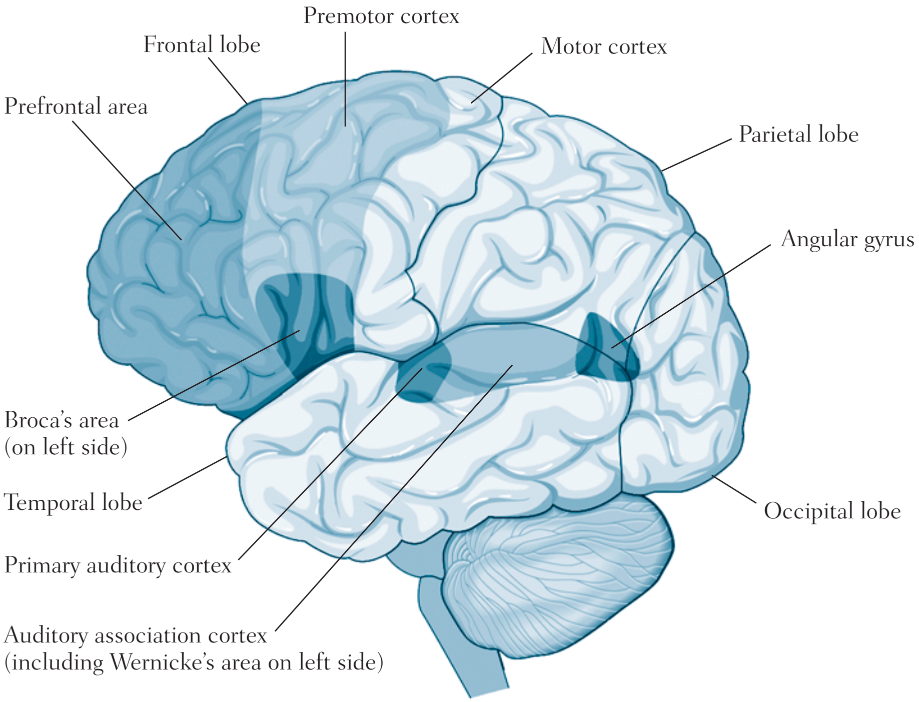
Image not available due to copyright restrictions

More modern approaches to localizing function in the brain date back to Paul Broca (1824–1880), who in the early 1860s presented findings at a medical conference that brain injury to a particular part of the left frontal lobe (the posterior, inferior region shown in Figure 2-6) resulted in a particular kind of **aphasia,** or disruption of expressive language (Springer & Deutsch, 1998). This brain region has become known as Broca's area; injury to this area leads to a kind of aphasia known as Broca's or nonfluent aphasia, in which the person is unable to produce many words or to speak very fluently.

A decade after Broca's discovery, Carl Wernicke (1848–1904) announced the discovery of a second "language center" in the brain, this one thought to control language understanding (as opposed to language production). This region, which has come to be known as Wernicke's area, is located in the superior,

**FIGURE 2-6** ■ *Classic speech centers.*

**SOURCE:** Wilson (2003, p. 227).


Premotor cortex
Frontal lobe
Motor cortex
Prefrontal area
Parietal lobe
Angular gyrus
Broca's area
(on left side)
Temporal lobe
Occipital lobe
Primary auditory cortex
Auditory association cortex
(including Wernicke's area on left side)

posterior region of the temporal lobe, also typically in the left hemisphere, and is also shown in Figure 2-6. Patients with so-called Wernicke's aphasia (also called fluent aphasia) are able to produce speech with seemingly fluent contours of pitch and rhythm. However, the speech often makes no sense and contains gibberish. Moreover, these patients show impairments in their ability to understand speech (Pritchard & Alloway, 1999).

Work by other neuropsychologists began to establish connections between lesions in particular brain regions and loss of specific motor control or sensory reception. Using research performed either on animals or as part of neurosurgical procedures intended to address problems such as epilepsy, scientists began to "map out" the portion of the frontal lobe known as the motor cortex, as shown in Figure 2-7.

In addition, neuropsychologists have mapped out a second area of the brain, located in the parietal lobe just behind the motor cortex, known as the **primary somatosensory cortex** (see Figure 2-8). Like the motor cortex, the primary somatosensory cortex is organized such that each part of it receives information from a specific part of the body. As with the motor cortex, the total amount of "brain real estate" devoted to a particular part of the body is not

**FIGURE 2-7** ■ *The motor cortex in the frontal lobe. Neurons in the motor cortext stimulate motor neurons that control specific muscles in the body.*

**SOURCE:** Wilson (2003, p. 157).

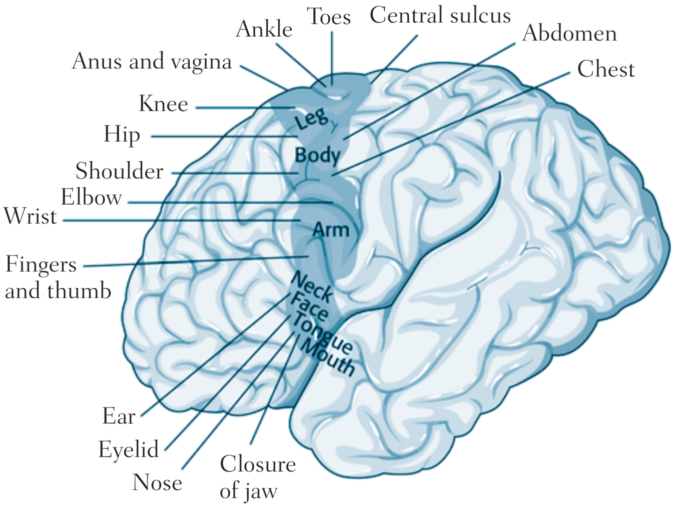
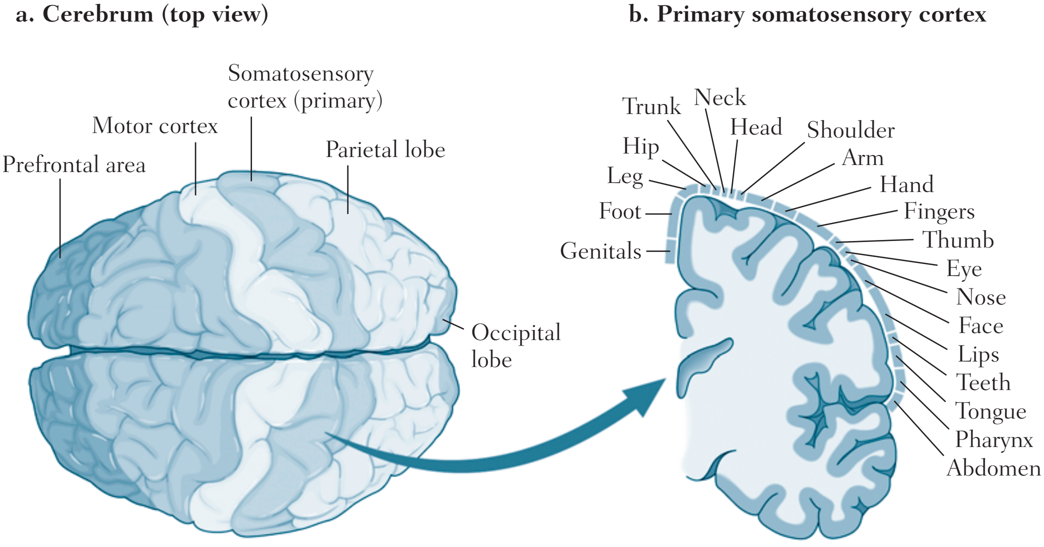

Ankle
Toes
Central sulcus
Abdomen
Anus and vagina
Chest
Knee
Leg
Hip
Body
Shoulder
Elbow
Wrist
Arm
Fingers and thumb
Neck
Face
Tongue
Mouth
Ear
Eyelid
Nose
Closure of jaw

**FIGURE 2-8** ■ *Primary and secondary somatosensory areas. The primary and secondary somatosensory areas are located in the parietal lobe. Like the motor cortex, the primary somatosensory cortex is topographically organized.*

**SOURCE:** Wilson (2003, p. 234).


a. Cerebrum (top view)
b. Primary somatosensory cortex
Somatosensory cortex (primary)
Motor cortex
Prefrontal area
Parietal lobe
Occipital lobe
Trunk
Neck
Head
Shoulder
Hip
Arm
Leg
Hand
Foot
Fingers
Genitals
Thumb
Eye
Nose
Face
Lips
Teeth
Tongue
Pharynx
Abdomen

proportional to the size of that body part. In other words, a large region of the body, such as a leg, corresponds to only a small portion of the primary somatosensory cortex. A more sensitive body part, such as the fingers or lips, has a correspondingly larger amount of cortex devoted to it.

The previous discussion may have given you the idea that every part of the brain can be mapped to some specific sensation, behavior, idea, thought, memory, or cognitive processes. This idea, however, is false. Although motor and sensory reception have the kinds of mapping depicted in Figures 2-7 and 2-8, most so-called higher order cognitive processes, such as thinking and remembering, do not.

Many neuroscientists subscribe to the principle that higher order cognitive processes are too complicated and interconnected to be localized to any one region (Pritchard & Alloway, 1999). This view drew support from the work of Karl Lashley (1890–1958), who performed several landmark studies in neuroscience, studying the effects of brain **ablation** (removal of parts of the brain) on the maze-running ability of rats. Lashley (1929) reported that impairment in maze running was related to the total amount of cortex removed, not to which specific area was removed.

Complicating this already involved picture is the notion of the **plasticity** of the brain (Black, 2004). Some brain regions can adapt to "take over" functions of damaged regions, depending on the injury and the function involved. In general, the younger the patient and the less extensive the injury, the better is the chance of regaining function.

## ■ LATERALIZATION OF FUNCTION

Paul Broca's report of a "language center" in his patients did more than argue for localization of function. Broca and many neuropsychologists since have been able to show that the two cerebral hemispheres seem to play different roles when it comes to some cognitive functions, especially language. We call this phenomenon **lateralization.**

Most individuals (around 95%) show a specialization for language in the left hemisphere. In these individuals, the left hemisphere is likely to be larger in size, especially in the areas where language is localized (Springer & Deutsch, 1998). We say that these individuals have a left-hemisphere dominance in language. A small percentage or people do not show such specialization, having language function in both hemispheres (these are called *bilateralized* individuals), and an even smaller percentage have language centers located in the right hemisphere.

If the left hemisphere is dominant for language, then what role does the right hemisphere play? Structurally, the right hemisphere often has larger parietal and temporal areas, and it is speculated that this leads to better integration of visual and auditory information and better spatial processing by the right than the left hemisphere. The right hemisphere is associated with working on geometric puzzles, navigation around familiar spaces, and even musical ability (Springer & Deutsch, 1998).

Some describe the difference in function between the two hemispheres by labeling the left hemisphere as the analytical one and the right hemisphere as the synthetic one (Carlson, 2004). The idea here is that the left hemisphere is particularly good at processing information serially—that is, information with events occurring one after another. If you think about processing a sentence, the events would be the individual words that are spoken or read in sequence. By contrast, the right hemisphere is thought to be more synthetic, putting individual elements together to make up a whole. Cognitive processes here might include constructing maps or other spatial structures, drawing sketches, and navigating through mazes.

Popular press articles have made much of the difference between the two cerebral hemispheres, going so far in some cases as to classify people as either right-brained or left-brained. It's very important to remember that this is a gross oversimplification. The vast majority of individuals have two quite functional cerebral hemispheres that continually interact to process information and carry out cognitive functions. The odds that only one hemisphere would be active in any everyday task are remote. Moreover, the two hemispheres are connected by a large neural structure known as the **corpus callosum,** which sends information from one hemisphere to another very quickly.

## ■ BRAIN IMAGING TECHNIQUES

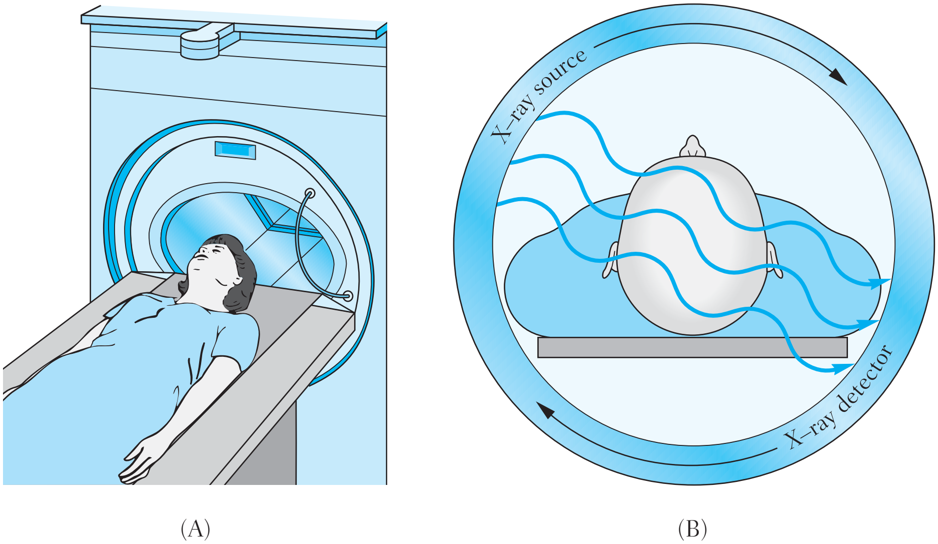
In Broca's day, neurologists had to wait until a patient died to really investigate the structural features of his or her brain. In the early part of the 20th century, more information came from studies performed as patients underwent brain surgery—to remove a tumor or stop the spread of epilepsy, most commonly. Fortunately for people but unfortunately for science, ethical considerations precluded doing brain surgery on healthy people, which limited our understanding of how "normal" brains functioned.

However, in the last four decades, technology has advanced to the point where neurologists and neuropsychologists can examine the functioning of normal brains using noninvasive means. We will briefly review some of these methods, known collectively as brain imaging techniques.

Some of these methods give us information about neuroanatomy—the structures of the brain. One of the earliest such brain-imaging techniques, developed in the 1970s, was X ray computed tomography—also called X ray CT, **computerized axial tomography,** or **CAT** scan—a technique in which a highly focused beam of X rays is passed through the body from many different

**FIGURE 2-9 ■** *CT scanner. A person's head is placed into the device (A), and then a rapidly rotating source sends X rays through the head while detectors on the opposite side make photographs (B). A computer then constructs an image of the brain.*

**SOURCE:** Kalat (1995, p. 136).



angles. Differing densities of body organs (including the brain) deflect the X rays differently, allowing visualization of the organ. Figure 2-9 depicts a person undergoing a CAT scan.

Typically, CAT scans of a person's brain result in 9 to 12 different "slices" of the brain, each one taken at a different level of depth. CAT scans depend on the fact that structures of different density show up differently. Bone, for example, is denser than blood, which is denser than brain tissue, which is in turn denser than cerebrospinal fluid (Banich, 2004). Recent brain hemorrhages are typically indicated by the presence of blood; older brain damage, by areas of cerebrospinal fluid. Thus clinicians and researchers can use CAT scans to pinpoint areas of brain damage and also to make inferences about the relative "age" of the injury.

Although an important diagnostic tool in neuropsychology, CAT scans are used less often than a newer brain-imaging technique, **magnetic resonance imaging,** or **MRI.** Like CAT scans, MRI provides information about neuroanatomy. Unlike CAT scans, however, MRI requires no exposure to radiation and often permits clearer pictures, as you can see in Figure 2-10 (D), which shows an MRI scan of a brain.

Someone undergoing an MRI typically lies inside a tunnel-like structure that surrounds the person with a strong magnetic field. Radio waves are directed

Images not available due to copyright restrictions

at the head (or whatever body structure is being scanned), causing the centers of hydrogen atoms in those structures to align themselves in predictable ways. Computers collate information about how the atoms are aligning and produce a composite three-dimensional image from which any desired cross section can be examined further.

MRI scans are often the technique of choice, as they now produce "textbook-quality anatomy pictures" of a brain (Carlson, 2004, p. 192). However, not everyone can undergo an MRI scan. The magnetic fields generated in an MRI scan interfere with electrical fields, so people with pacemakers are not candidates for an MRI (pacemakers generate electric signals). Neither are people with metal in their bodies, such as a surgical clip on an artery or a metal shaving in the eye. The magnetic field could dislodge the metal in the body, causing trauma. Metal anchored to hard surfaces, such as dental fillings, is not a problem. Because MRIs require people to lie very still in a tunnel-like machine that often leaves little room for arm movements; people with claustrophobia are also not good candidates for this technique.

As I've already mentioned, these two techniques provide pictures of brain structures, and investigators can use these pictures to pinpoint areas of damage or other abnormality. However, these scans provide relatively static pictures of the parts of a brain and do not give much information about how a brain functions—that is, what areas of the brain show activity when people perform different tasks. To answer such questions, different brain-imaging techniques are needed. Fortunately, recent developments have created techniques that fit the bill.

A functional brain-imaging technique that also dates back to the 1970s is called **positron emission tomography,** or **PET.** This technique involves injecting a radioactively labeled compound (radioisotopes of carbon, nitrogen, oxygen, or fluorine, subatomic particles that rapidly emit gamma radiation, which can be detected by devices outside the head). PET scans measure the blood flow to different regions of the brain, allowing an electronic reconstruction of a picture of a brain, showing which areas are most active at a particular time (Posner & Raichle, 1994). A variation of the PET procedure involves measuring local metabolic changes instead of blood flow, using an injection of fluorodeoxyglucose, a radioisotope structurally similar to glucose. Figure 2-10 (C) provides a black-and-white representation of a PET scan, although more typically such visualizations are presented in color.

PET scans rely on the fact that when an area of the brain is active, more blood flows to it, and its cells take up more glucose from the blood vessels that penetrate it (Frith & Friston, 1997; Kung, 1993). People undergoing a PET brain scan sit with their head in a ring of photocells. A radioactive tracer, typically $^{15}O_2$ (oxygen with one electron removed), is injected into a vein as water (that is, as $H_2{}^{15}O$). Within 30 seconds, the tracer starts to reach the brain. The tracer $^{15}O$ accumulates in the brain in direct proportion to the amount of blood flowing to that brain region (Banich, 2004). Within the roughly 2 minutes before the radioactive tracer decays to its half-life, several scans can be made, showing the amount of blood flowing to that region (Frith & Friston, 1997).

Another technique to measure cerebral blood flow is known as single-photon emission computed tomography, or SPECT for short. The basic technique is similar to a PET scan, but does not require some of the expensive equipment a PET scan does; thus it is sometimes known as a "poor person's PET" (Zillmer & Spiers, 2001).

Like CAT scans, PET and SPECT scans use radiation. Moreover, PET scans show activity averaged over some amount of time, approximately a minute and a half (for the tracer $^{15}O$) up to an hour, making it hard to pinpoint the time course of the brain activity. PET scans can also require very expensive equipment not widely available.

A newer technique may offer a way out of these difficulties. **Functional magnetic resonance imaging,** or **fMRI,** relies on the fact that blood has magnetic properties. As blood is carried from the heart, it is maximally magnetic.

Roger Ressmeyer/CORBIS

*A person undergoing a PET scan, with results showing on the screen at right.*

As it passes through capillaries, it becomes less magnetic. Brain regions that show activity show a change in the ratio of oxygenated to deoxygenated blood (Banich, 2004). Such fMRI scans use existing MRI equipment but provide clinicians and investigators with a noninvasive, nonradioactive means of assessing blood flow to various brain regions.

These techniques for studying the way the brain functions make possible new connections and new questions in cognitive psychology. Before the availability of these techniques, cognitive theories did not refer to the biological mechanisms that implement various cognitive processes. Now cognitive neuroscientists offer us findings from studies based on a new assumption: "The mapping between physical activity in the brain and its functional state is such that when two experimental conditions are associated with different patterns of neural activity, it can be assumed that they have engaged distinct cognitive functions" (Rugg, 1997, p. 5). A review of 275 PET and fMRI studies (Cabeza & Nyberg, 2000), for example, showed different areas of activation for different cognitive functions: attention, perception, imagery, language, and memory.

Another "window on the brain" can be obtained through electrical recording methods. You may already know that when neurons in the brain (or anywhere else, for that matter) fire, they generate electrical activity. Some animal research has involved placing electrodes in individual neurons to detect when and how often those single cells fire. Such work is not done with humans.

Instead, the sum total of electrical activity generated by a large number of neurons comprises the information gathered (Banich, 2004).

**Electroencephalography (EEG)** is used to detect different states of consciousness. Metal electrodes are positioned all over the scalp. The waveforms record changes in predictable ways when the person being recorded is awake and alert, drowsy, asleep, or in a coma. EEGs provide the clinician or researcher with a continuous measure of brain activity (Banich, 1997). A newer technique, magnetoencephalography, or MEG, measures changes in magnetic fields generated by electrical activities of neurons. It has been called the "magnetic equivalent" of EEG (Springer & Deutsch, 1998). MEG gives a more precise localization of brain region activity than does EEG.

Another electrical recording technique, called **event-related potential,** or **ERP,** measures an area of the brain's response to a specific event. Participants in an ERP study have electrodes attached to their scalp and are then presented with various external stimuli, such as sights or sounds. The recording measures brain activity from the time before the stimulus is presented until some time afterward. The brain waves recorded also have predictable parts, or components. That is, the shape of the waveform can vary depending on whether or not the participant expects the stimulus to occur or is attending to the location in which the stimulus appears and whether the stimulus is physically different from other recent stimuli.

Brain imaging and recording techniques certainly include a lot of acronyms! How can the novice keep them all straight? One way to do so is to categorize the techniques according to the kind of information they provide. CAT and MRI scans yield neuroanatomical information. PET, SPECT, and fMRI provide dynamic information about how blood flows during various cognitive activities. MEG, EEG, and ERPs all measure electrical activity during cognitive activities. In the chapters to come, we will see examples of studies that have made use of each of these techniques to investigate the neural underpinnings of different cognitive activities.

We have covered a lot of ground in this chapter, and yet we have still only begun to grapple with the complexities of the human brain. The interested student should refer to a text on neuropsychology, physiology, or biological psychology for more detail on any of the topics introduced here (see, for example, Banich, 2004, and Zillmer & Spiers, 2001).

What is important to remember is that cognitive processes are implemented in human brains. Some researchers make an analogy between human minds and computers; in this view, the brain is the "hardware" ("wetware") and the cognitive processes the software. Although the two aspects of functioning can be distinguished, to really understand either we must have some familiarity with both, and with how they interact. We'll return to this idea throughout the upcoming chapters.

## SUMMARY

1. The hindbrain, containing some of the most evolutionarily primitive structures, is responsible for transmitting information from the spinal cord to the brain, regulating life support functions, and helping to maintain balance.
2. The midbrain contains many "relay" centers to transfer information between different brain regions.
3. The forebrain contains the thalamus, hypothalamus, hippocampus, amygdala, and the cerebral cortex, structures that are most directly implicated in cognitive processes such as memory, language, planning, and reasoning.
4. The cerebral cortex has four lobes: frontal (involved with movement and planning), parietal (involving reception and integration of sensory information), occipital (processing visual information), and temporal (processing auditory information as well as information about taste and smell).
5. Although some specific brain areas have specific functions localized to them (for example, the motor cortex or the primary somatosensory cortex), most higher order cognitive processes do not map to one specific neural area.
6. Aphasia, a disorder of language, has been traced to two different areas of the brain, Broca's area and Wernicke's area, although other brain areas are likely involved as well.
7. Cerebral hemispheres have been shown to be lateralized in many individuals, with the left hemisphere usually processing analytical information and the right hemisphere synthesizing information. In normal operation, however, the two hemispheres communicate extensively.
8. A variety of modern techniques have been developed to measure the functioning of the brain during cognitive processing. Among the major techniques are CAT scans, MRI, PET scans, fMRI, EEG recordings, and ERP recordings.

## REVIEW QUESTIONS

1. Predict which brain areas are likely to be most involved with the cognitive processes of perception, attention, memory, language, and problem solving. Provide a rationale for your predictions.
2. Describe the functions of the four lobes of the cerebral cortex.
3. Explain how modern-day localization of brain function differs from phrenology.
4. What does it mean to say that the cerebral hemispheres show lateralization? What is the typical pattern of lateralization?
5. Compare and contrast the various brain imaging and brain recording techniques.

## Key Terms

- ablation
- amygdala
- aphasia
- CAT (computerized axial tomography)
- cerebellum
- cerebral cortex
- corpus callosum
- EEG (electroencephalography)
- ERP (event-related potential)
- executive functioning
- faculty psychology
- fMRI (functional MRI)
- forebrain
- frontal lobe
- hindbrain
- hippocampus
- hypothalamus
- lateralization
- localization of function
- medulla oblongata
- midbrain
- motor cortex
- MRI (magnetic resonance imaging)
- occipital lobe
- parietal lobe
- PET (positron emission tomography)
- phrenology
- plasticity
- pons
- prefrontal cortex
- primary somatosensory cortex
- temporal lobe
- thalamus

## CogLab Demonstrations

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

If you have access to CogLab, a web-based set of demonstrations in cognitive psychology, you may want to try the **Brain Asymmetry, Mapping the Blind Spot,** and **Receptive Fields** demonstrations, which will give you some of the flavor of a research enterprise in cognitive neuroscience investigations.

## Web Resources

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

PART

# II

# Basic Processes

3 Perceiving Objects and Recognizing Patterns
4 Paying Attention
5 Forming and Using New Memory Traces
6 Retrieving Memories From Long-Term Storage

# CHAPTER

# 3

# Perceiving Objects and Recognizing Patterns

**Gestalt Approaches to Perception**

**Bottom-Up Processes**
- Template Matching
- Featural Analysis
- Prototype Matching

**Top-Down Processes**
- Perceptual Learning
- Change Blindness
- The Word Superiority Effect
- A Connectionist Model of Word Perception
- A Neuroscientific Perspective on Word Perception

**Direct Perception**

**Disruptions of Perception: Visual Agnosias**

Look across the room right now, and notice the objects you see. Maybe, if you are looking out a window, you see some trees or bushes, perhaps a bicycle or car, maybe a person walking or a group of children playing.

What you've just done, cognitively speaking, is an amazing achievement: You've taken sensory input and interpreted it meaningfully, in a process known as **perception.** In other words, you have perceived patterns, objects, people, and possibly events in your world. You may not consider this achievement at all remarkable—after all, it's something you do every day. However, computer scientists trying to create artificially intelligent systems have discovered just how complicated the process of perception is. Neuroscientists have estimated that the areas of our brain responsible for visual processing occupy up to half of the total cortex space (Tarr, 2000).

The central problem of perception is explaining how we attach meaning to the sensory information we receive. In the example just given, you received and somehow interpreted a great deal of sensory information: You "saw" certain objects as trees, people, and so forth. You recognized certain objects—that is, saw them as things you had seen before. The question for cognitive psychologists is how we manage to accomplish these feats so rapidly and (usually) without error.

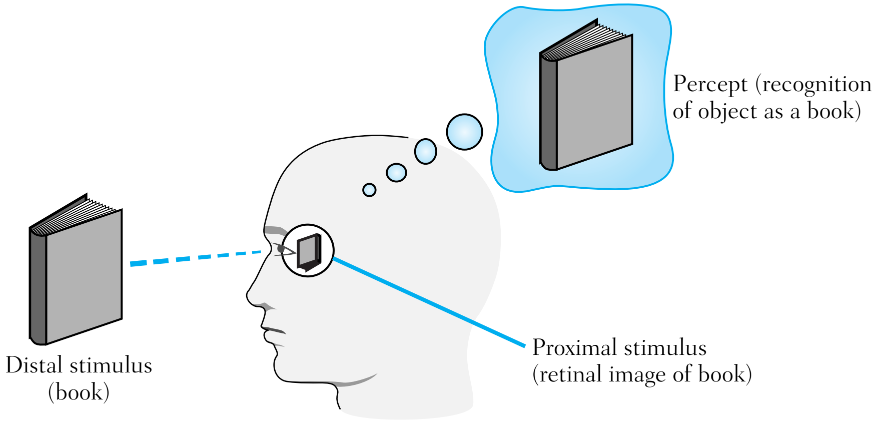
The vast topic of perception can be subdivided into visual perception, auditory perception (the two best studied forms), olfactory perception, haptic (touch) perception, and gustatory (taste) perception. For the purposes of this chapter, we will concentrate on visual perception—in part to keep our discussion manageable and in part because visual perception is the kind psychologists study most. From time to time, we will also look at examples of other kinds of perception to illustrate different points.

Notice that when you look at an object, you acquire specific bits of information about it, including its location, shape, texture, size, and (for familiar objects) name. Some psychologists—namely, those working in the tradition of James Gibson (1979)—would argue that you also immediately acquire information about the object's function. Cognitive psychologists seek to describe how people acquire such information and what they then do to process it.

Several related questions immediately arise. How much of the information we acquire through perception draws on past learning? How much of our perception do we infer, and how much do we receive directly? What specific cognitive processes enable us to perceive objects (and events, and states, and so on)? Where can the line be drawn between perception and sensation, the initial reception of information in a specific sensory modality—vision, hearing, olfaction? Where can the line be drawn between perception and other kinds of cognition, such as reasoning or categorization? Clearly, even defining perception so as to answer these questions is a challenge.

For the present, we will adopt what might be called the "classic" approach to defining perception. Figure 3-1 illustrates this approach for visual perception. Out in the real world are objects and events—things to be perceived—a book or, as in my earlier example, trees and shrubs. Each such object is a **distal stimulus.** For a living organism to process information about these stimuli, it must first receive the information through one or more sensory systems—in this example, the visual system. The reception of information and its registration by a sense organ make up the **proximal stimulus.** In our earlier example, light waves reflect from the trees and cars to your eyes, in particular to a surface at the back of each eye known as the **retina.** There, an image of the trees and cars, called the **retinal image,** is formed. This image is two-dimensional, and its size depends on your distance from the window and the objects beyond (the closer you are, the larger the image). In addition, the image is upside down and is reversed with respect to left and right.

**FIGURE 3-1** ■ *Distal stimuli, proximal stimuli, and percepts.*



The meaningful interpretation of the proximal stimulus is the **percept**—your interpretation that the stimuli are trees, cars, people, and so forth. From the upside-down, backward, two-dimensional image, you quickly (almost instantaneously) "see" a set of objects you recognize. You also "recognize" that, say, the giant oak tree is closer to you than are the lilac shrubs, which appear to recede in depth away from you. This information is not part of the proximal stimulus. Somehow, you must interpret the proximal stimulus to know it.

Although researchers studying perception disagree about much, they do agree that percepts are not the same things as proximal stimuli. Consider a simple demonstration of **size constancy.** Extend your arm away from your body, and look at the back of your hand. Now, keeping the back of your hand facing you, slowly bring it toward you a few inches, then away from you. Does your hand seem to be changing size as it moves? Probably not, although the size of the hand in the retinal image is most certainly changing. The point here is that perception involves something different from the formation of retinal images.

Related to perception is a process called **pattern recognition.** This is the recognition of a particular object, event, and so on, as belonging to a class of objects, events, and so on. Your recognition of the object you are looking at as belonging to the class of things called "shrubs" is an instance of pattern recognition. Because the formation of most percepts involves some classification and recognition, most, if not all, instances of perception involve pattern recognition.

We will begin by considering proposals from the Gestalt school of psychology that perception involves the segmentation, or "parsing," of visual stimuli into objects and backgrounds (and just how complicated this seemingly easy process is). We will then turn to examine some (mostly) bottom-up models of perception. Then we will examine phenomena that have led many cognitive psychologists to argue that some top-down processes must occur in perception in interaction with bottom-up processing. We will examine some neurological findings pertaining to object perception and will also consider a connectionist model of word perception.

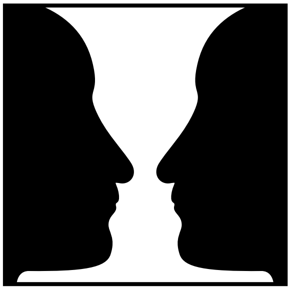
We will then review a very different view: work inspired by J. J. Gibson (1979) on "direct perception." Gibson's view departs from most other theories of perception in that he claims perceivers actually do little "processing" of information, either bottom-up or top-down. Instead, he believes the information available in the world is sufficiently rich that all the perceiver needs to do is detect or "pick up on" that information. We will conclude by looking at some neuropsychological work on patients who have an inability to perceive (but have intact visual abilities) to help illustrate just what the process of perception is all about.

## ■ GESTALT APPROACHES TO PERCEPTION

One of the most important aspects of visual perception has to do with how we interpret stimulus arrays as consisting of objects and backgrounds. Consider, for instance, Figure 3-2. This stimulus pattern can be seen in two distinct ways: as a white vase against a black background or as two silhouetted faces against a white background. This segregation of the whole display into objects (also called the figure) and the background (also called the ground) is an important process known to cognitive psychologists as **form perception.**

Reversible figures aren't just for perceptual psychologists, either! The artist Salvador Dali exploits the existence of reversible figures in his work *The Slave Market with Disappearing Bust of Voltaire,* shown in the top half of Figure 3-3. Psychologist Robert Solso, who has written on the intersection of cognitive psychology and the visual arts, presents a "blowup" of the hidden "bust of Voltaire" in the bottom half of the figure.

**FIGURE 3-2** ■ *Goblet/silhouetted faces.*

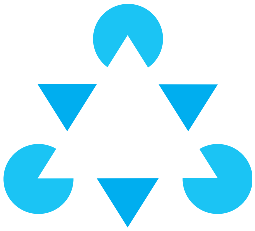


Images not available due to copyright restrictions

The segregation of figure from ground has many consequences. The part of the display seen as figure is seen as having a definite shape, as being some sort of "thing," and is better remembered than the part of the display interpreted as ground, which is seen as more shapeless, less formed, and farther away in space (Brown & Deffenbacher, 1979). Form perception is a cognitive task most of us perform quickly and easily and thus take for granted. We assume, intuitively, that we perceive objects and backgrounds because there really *are* objects and backgrounds and all we do is see them.

But consider Figure 3-4. Almost everyone sees this figure as consisting of two triangles, overlaid so as to form a six-pointed star. The corners of the top triangle are typically seen as resting on three colored circles. Now look closely at the figure, in particular at the top triangle. Recall that a triangle is defined as a closed geometric figure that has three sides. Notice that in the figure itself there are *no* sides. There is only white space that you, the viewer, interpret as a triangle. You, the viewer, are somehow adding the three sides or contours.

**FIGURE 3-4** ■ *Subjective, or illusory, contours.*



Gregory (1972), who studied this phenomenon (called illusory contours or **subjective contours**), believed that this relatively complex display is subject to a simplifying interpretation the perceiver makes without even being aware of making it: A triangle is lying on top of other parts of the figure and blocking them from view. The point here is that this perception is not completely determined by the stimulus display; it requires the perceiver's active participation.

A number of individuals in the early part of the 20th century—among them, Max Wertheimer, Kurt Koffka, and Wolfgang Köhler—were deeply interested in how perceivers come to recognize objects or forms. As we saw in Chapter 1, these researchers, who formed the Gestalt school of psychology, were particularly concerned with how people apprehended *whole* objects, concepts, or units. The Gestalt psychologists believed that perceivers follow certain laws or principles of organization in coming to their interpretations. They first asserted that the whole, or *Gestalt,* is not the same as the sum of its parts. To put it another way, Gestalt psychologists rejected the claim that we recognize objects by identifying individual features or parts; instead, we see and recognize each object or unit as a whole.

What are the **Gestalt principles of perceptual organization** that allow us to see these wholes? The complete list is too long to describe (see Koffka, 1935), so we will examine only five major principles. The first is the *principle of proximity,* or nearness. Look at Figure 3-5(A). Notice that you tend to perceive this as a set of rows, rather than as a set of columns. This is because the elements within rows are closer than the elements within columns. Following the principle of proximity, we group together things that are nearer to each other.

Figure 3-5(B) illustrates the *principle of similarity.* Notice that you perceive this display as formed in columns (rather than rows), grouping together those elements that are similar. A third principle, the *principle of good continuation,* depicted in Figure 3-5(C), states that we group together objects whose contours form a continuous straight or curved line. Thus we typically perceive

**FIGURE 3-5** ■ *Gestalt principles of perceptual organization: (A) the principle of proximity; (B) the principle of similarity; (C) and (D) the principle of good continuation; (E) the principle of closure; and (F) the principle of common fate (see text for further explanation).*

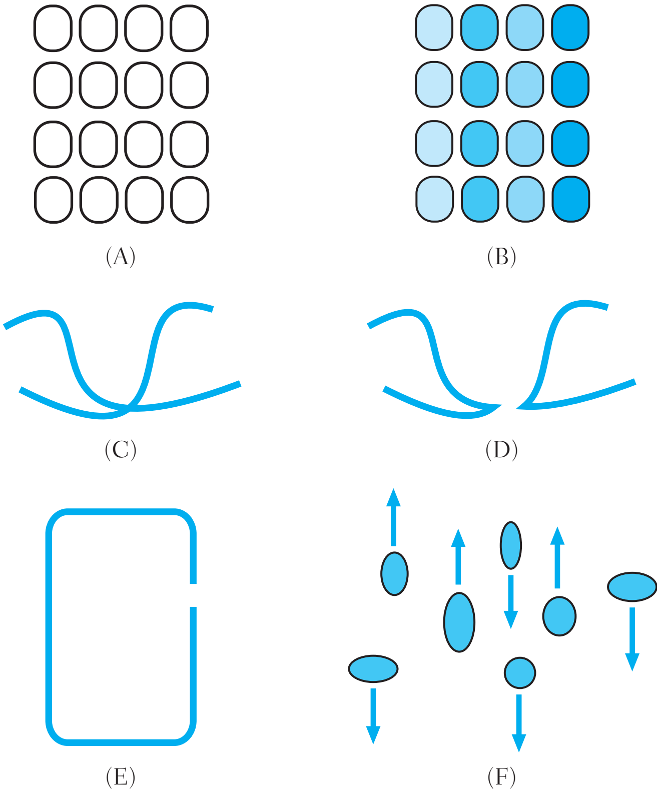


Figure 3-5(C) as two intersecting curved lines and not as other logically possible elements, such as Figure 35(D).

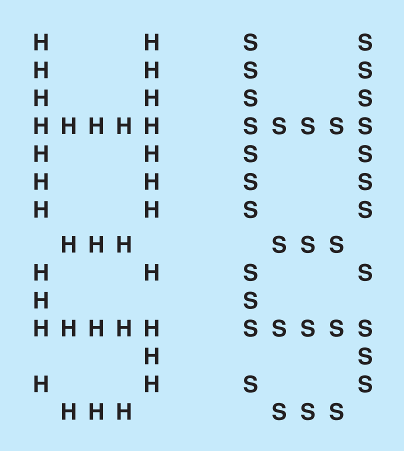
We encountered the fourth principle, the *principle of closure,* when we looked at subjective contours. Figure 3-5(E) illustrates this principle more exactly. Note that we perceive this display as a rectangle, mentally filling in the gap to see a closed, complete, whole figure. The fifth principle, the *principle of common fate,* is difficult to illustrate in a static drawing. The idea is that elements that move together will be grouped together, as depicted in Figure 3-5(F). You can construct a better demonstration of this principle yourself (Matlin, 1988). Take two pieces of transparent plastic (such as report covers cut in half). Glue some scraps of paper on each. Lay one sheet upside down on top of the other, and you will have a hard time telling which sheet of plastic any particular scrap is on. Now move one sheet, holding the other still. You will suddenly see two distinct groups of scraps.

Most of the Gestalt principles are subsumed under a more general law, the *law of Prägnanz* (Koffka, 1935). This law states that of all the possible ways of interpreting a display, we will tend to select the organization that yields the simplest and most stable shape or form. Thus simple and symmetric forms are seen more easily than more complicated and asymmetric forms. This law may help to explain our experience of Figure 3-4 with subjective contours. Because the phantom "triangle" forms a simple, symmetric form, we "prefer" to interpret the pattern as if the triangle were there.

In recent work, cognitive psychologists have shown a reawakened interest in Gestalt principles. Consider Figure 3-6, and quickly describe what you see. Did you first see four large letters: *H, H, S,* and *S?* If so, this is what most

**FIGURE 3-6** ■ *Compound letters.*

**SOURCE:** Kimchi (1992, p. 26).



people report seeing first. But look more closely. The second *H* and the first *S* are actually made up of little *S*'s and *H*'s, respectively. And indeed, in these two figures, the processing doesn't seem to be disrupted by the fact that the elementary units (for example, little *H*'s) have entirely different angles and parts (for example, straight lines) from the larger figure that they compose (for example, the curves in the *S*). The perceptual immediacy of the larger figure over the smaller components is well known and documented (Kimchi, 1992).

Many researchers of visual perception consider the Gestalt principles fundamental (Tarr, 2000), and researchers are beginning to demonstrate the use of some Gestalt principles by infants as young as three to six months (Quinn, Bhatt, Brush, Grimes, & Sharpnack, 2002). Some work on formalizing the Gestalt law of Prägnanz has begun, with a new theory called *minimal model theory* (Feldman, 1999).

Despite its intuitive appeal, the Gestalt approach to form perception leaves a number of questions unanswered (Pomerantz & Kubovy, 1981). We don't know, for instance, just how these principles are translated into cognitive or physiological processes. Moreover, without further specification the law of Prägnanz can be seen as circular. (Why do we see two triangles in Figure 3-4? Because this interpretation makes for a simple, stable figure. How do we know this figure is simple and stable? Because we so readily see it.)

Many cognitive psychologists studying perception acknowledge their debt to the Gestalt psychologists. The challenge for current researchers is to blend the rich observations of Gestalt psychology with research techniques designed to tell us just how the processes used to form perception operate.

## BOTTOM-UP PROCESSES

Psychologists studying perception distinguish between **bottom-up** and **top-down processes.** The term *bottom-up* (or *data-driven*) essentially means that the perceiver starts with small bits of information from the environment that he combines in various ways to form a percept. A bottom-up model of perception and pattern recognition might describe your seeing edges, rectangular and other shapes, and certain lighted regions and putting this information together to "conclude" you are seeing doors and a hallway. That is, you would form a perception from only the information in the distal stimulus.

In *top-down* (also called *theory-driven* or *conceptually driven*) processing, the perceiver's expectations, theories, or concepts guide the selection and combination of the information in the pattern recognition process. For example, a "top-down" description of the door-and-hallway example might go something like this: You knew you were in your dorm room and knew from past experience approximately how close to the window the various trees, shrubs, and other objects were. When you looked in that direction, you expected to see trees, shrubs, walkways with people on them, a street with cars riding by, and so on. These expectations guided where you looked, what you looked at, and how you put the information together.

In this section, we will focus on bottom-up models. The idea here is that the system works in one direction, starting from the input and proceeding to a final interpretation. Whatever happens at a given point is unaffected by later processing; the system has no way of going back to an earlier point to make adjustments.

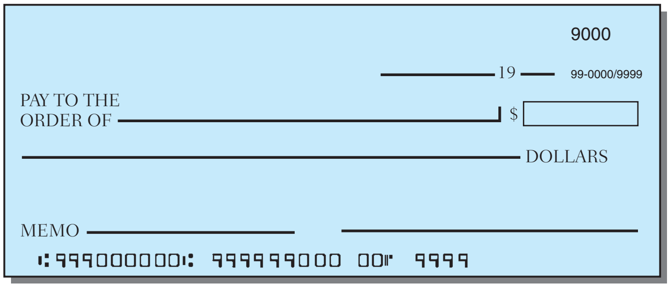
To picture bottom-up processing, imagine a row of students seated at desks. The student in the last seat of the row starts the process by writing a word down on a piece of paper and handing the paper to the student in front of her. That student adds some information (maybe another word, maybe an illustration) and, in turn, hands the paper to the student in front of him, and so on, until the paper reaches the student at the front of the row. Students at the front of the row have no opportunity to ask students behind them for any clarification or additional information.

When psychologists speak of bottom-up perceptual processes, they typically have in mind something that takes information about a stimulus (by definition a "lower" level of processing) as input. Bottom-up processes are relatively uninfluenced by expectations or previous learning (the so-called higher-level processes). Posner and Raichle (1994) argued that bottom-up processes involve automatic, reflexive processing that takes place even when the perceiver is passively regarding the information. In this section we will consider three distinct examples of bottom-up models of perception.

## Template Matching

Figure 3-7 shows a copy of a check. Notice the numbers at the bottom of the check. These numbers encode certain information about a checking account—the account number, the bank that manages it, and so forth. These numbers may look funny to you, but they wouldn't look at all funny to machines known

**FIGURE 3-7** ■ *A sample bank check. Note the numbers at the bottom.*



9000

19

99-0000/9999

PAY TO THE
ORDER OF

$

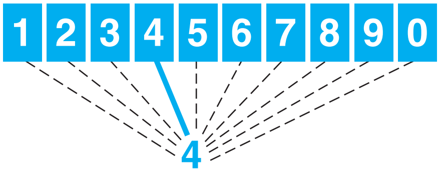
DOLLARS

MEMO

⑆999000000⑆ 999999000 00⑈ 9999

as *check sorters,* such as those the Federal Reserve banks use to sort checks and deliver them to the correct banks for payment. These machines “read” the numbers and compare them to previously stored patterns, called **templates.** The machines “decide” which number is represented by comparing the pattern to these templates, as shown in Figure 3-8. A tour of your local Federal Reserve bank can convince you that this system works most impressively.

**FIGURE 3-8** ■ *Illustration of template matching. The input “4” is compared either serially or simultaneously with all of the available templates. The match to “4” is the best.*



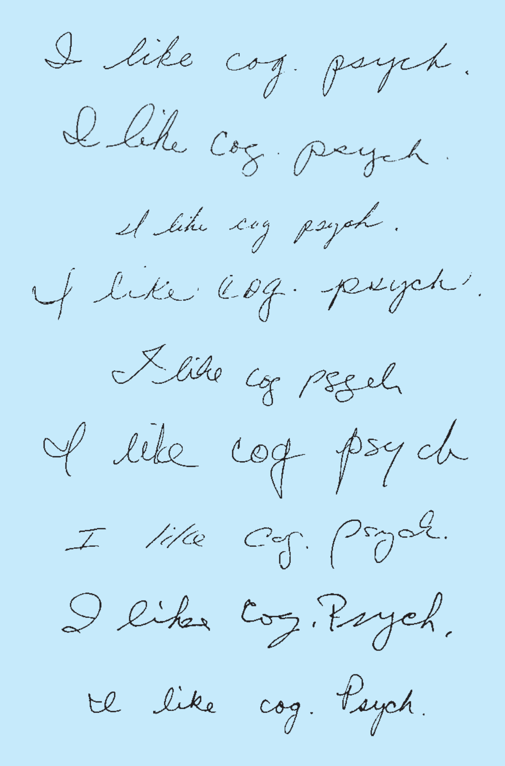
You can think of a template as a kind of stencil—one of the art supplies you probably owned as a child. If you remember, those stencils let you trace as many copies as you wanted of the same thing. Templates work like stencils in reverse. An unknown incoming pattern is compared to all of the templates (stencils) on hand and identified by the template that best matches it.

As a model of perception, template matching works this way: Every object, event, or other stimulus that we encounter and want to derive meaning from is compared to some previously stored pattern, or template. The process of perception thus involves comparing incoming information to the templates we have stored, and looking for a match. If a number of templates match or come close, we need to engage in further processing to sort out which template is most appropriate. Notice that this model implies that somewhere in our knowledge base we’ve stored millions of different templates—one for every distinct object or pattern we can recognize.

As may already be apparent to you, template-matching models cannot completely explain how perception works. First, for such a model to provide a complete explanation, we would need to have stored an impossibly large number of templates. Second, as technology develops and our experiences change, we become capable of recognizing new objects—DVDs, Palm Pilots, laptop computers, cellular phones. Template-matching models thus have to explain how and when templates are created and how we keep track of an ever-growing number of templates.

A third problem is that people recognize many patterns as more or less the same thing, even when the stimulus patterns differ greatly. Figure 3-9 illustrates this point. I constructed this figure by having nine people write the sentence “I like cog. psych.” in their own handwriting. You should be able to read

**FIGURE 3-9** ■ *Handwriting samples.*



I like cog. psych.
I like Cog. psych.
I like cog psych.
I like cog. psych.
I like cog psych
I like cog psych
I like cog. Psych.
I like Cog. Psych.
I like cog. Psych.

each sentence despite the wide variation in the size, shape, orientation, and spacing of letters.

How can a template-matching model explain your recognition that all nine people have written the "same" sentence? In everyday life, much of the stimulus information we perceive is far from regular, whether because of deliberate alteration, degradation, or an unfamiliar orientation (compare an overturned cup or bicycle with one that is right side up). Is a separate template needed for each variation? And how is the perceiver to know whether an object should be rotated or otherwise adjusted before she tries to match it to a template? Remember, matching information to templates is supposed to tell the perceiver what the object is. The perceiver can't know ahead of time whether an input pattern should be adjusted before he tries to match it to different templates, because presumably the perceiver does not yet know what the object is!

So although there are real technological examples of template matching, we probably don't rely heavily on such a process in our everyday perception. (We will consider a possible exception to this generalization when we talk about experiments involving mental rotation of line drawings, in Chapter 9.) Template matching works only with relatively clean stimuli, for which we know ahead of time what templates may be relevant. It does not adequately explain how we perceive as effectively as we typically do the "noisy" patterns and objects—blurred or faint letters, partially blocked objects, sounds against a background of other sounds—that we encounter every day.

## Featural Analysis

I'm staring at the object I perceive to be my office door. As I do, I'm able to recognize not only the whole door but also certain parts of it: the narrow edge facing me, the inside and outside doorknobs, the latch, the metal plate on the bottom of the outside of the door to protect it from scuffing. Some psychologists believe such analysis of a whole into its parts underlies the basic processes used in perception. Instead of processing stimuli as whole units, we might instead break them down into their components, using our recognition of those parts to infer what the whole represents. The parts searched for and recognized are called **features.** Recognition of a whole object, in this model, thus depends on recognition of its features.

Such a model of perception—called *featural analysis*—fits nicely with some neurophysiologic evidence. Some studies of the retinas of frogs (Lettvin, Maturana, McCullogh, & Pitts, 1959) involved implanting microelectrodes in individual cells of the retina. Lettvin et al. found that specific kinds of stimuli could cause these cells to fire more frequently. Certain cells responded strongly to borders between light and dark and were called "edge detectors"—"edge" because they fired when stimulated by a visual boundary between light and dark, "detectors" because they indicated the presence of a certain type of visual stimulus. Others responded selectively to moving edges, and others, jokingly called "bug detectors," responded most vigorously when a small, dark dot (much like an insect) moved across the field of vision. Hubel and Wiesel (1962, 1968) later discovered fields in the visual cortexes of cats and monkeys that responded selectively to moving edges or contours in the visual field that had a particular orientation. In other words, they found evidence of separate "horizontal-line detectors" and "vertical-line detectors," as well as other distinct detectors.

How does this evidence support featural analysis? Certain detectors appear to scan input patterns, looking for a particular feature. If that feature is present, the detectors respond rapidly. If that feature is not present, the detectors do not respond as strongly. Each detector, then, appears designed to detect the presence of just one kind of feature in an input pattern. That such detectors exist, in the form of either retinal or cortical cells, confirms the applicability of the featural analysis model.

Irving Biederman (1987) proposed a theory of object perception that uses a type of featural analysis that is also consistent with some of the Gestalt principles of perceptual organization discussed earlier. Biederman proposed that when people view objects, they segment them into simple geometric components, called **geons.** Biederman proposed a total of 36 such primitive components, some of which are pictured in Figure 3-10. From this base set of units, he believed, we can construct mental representations of a very large set of common objects. He made an analogy between object and speech perception: From the 44 **phonemes,** or basic units of sound, in the English language, we can represent all the possible words in English (a number well into the hundreds of thousands). Likewise, Biederman argued, from the basic set of 36 geons, we can represent the thousands of common objects we can quickly recognize.

As evidence for his theory (called "recognition by components"), Biederman offered Figure 3-11, a line drawing of a fictional object probably none of us has ever seen. Nonetheless, we would all show surprising agreement over

**FIGURE 3-10** ■ *Some examples of geons.*

**SOURCE:** Biederman (1987, pp. 122–123).

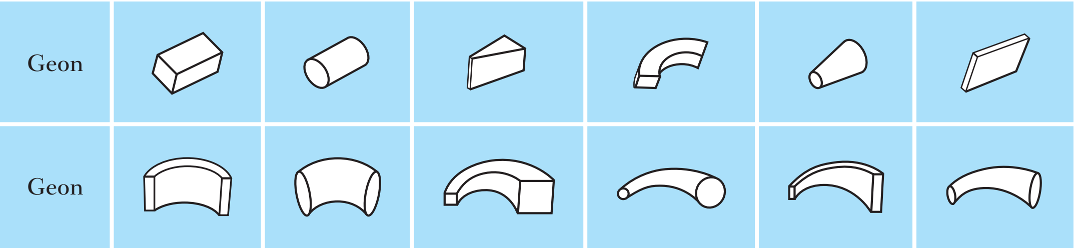
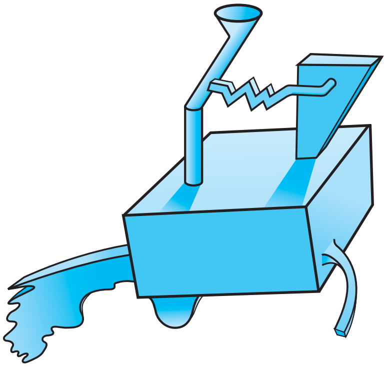


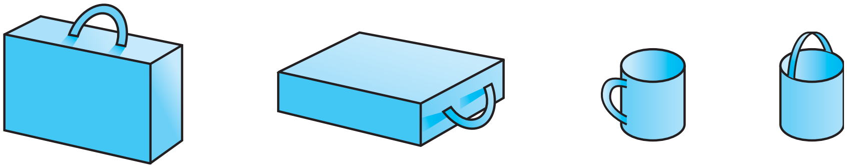
**FIGURE 3-11** ■ *A fictional object.*

**SOURCE:** Biederman (1987, p. 116).



what the "parts" of the unknown object are: a central "box," a wavy thing at the lower left, a curved-handled thing on the lower right, and so on. Biederman believed the same perceptual processes we use to divide this unknown figure into parts are used for more familiar objects. We divide the whole into the parts, or geons (named for "geometrical ions"; Biederman, 1987, p. 118). We pay attention not just to *what* geons are present but also to the *arrangement* of geons. As Figure 3-12 shows, the same two geons combined in different ways can yield very different objects.

**FIGURE 3-12** ■ *Different objects containing the same geons in different arrangements.*
**SOURCE:** Biederman (1987, p. 119).



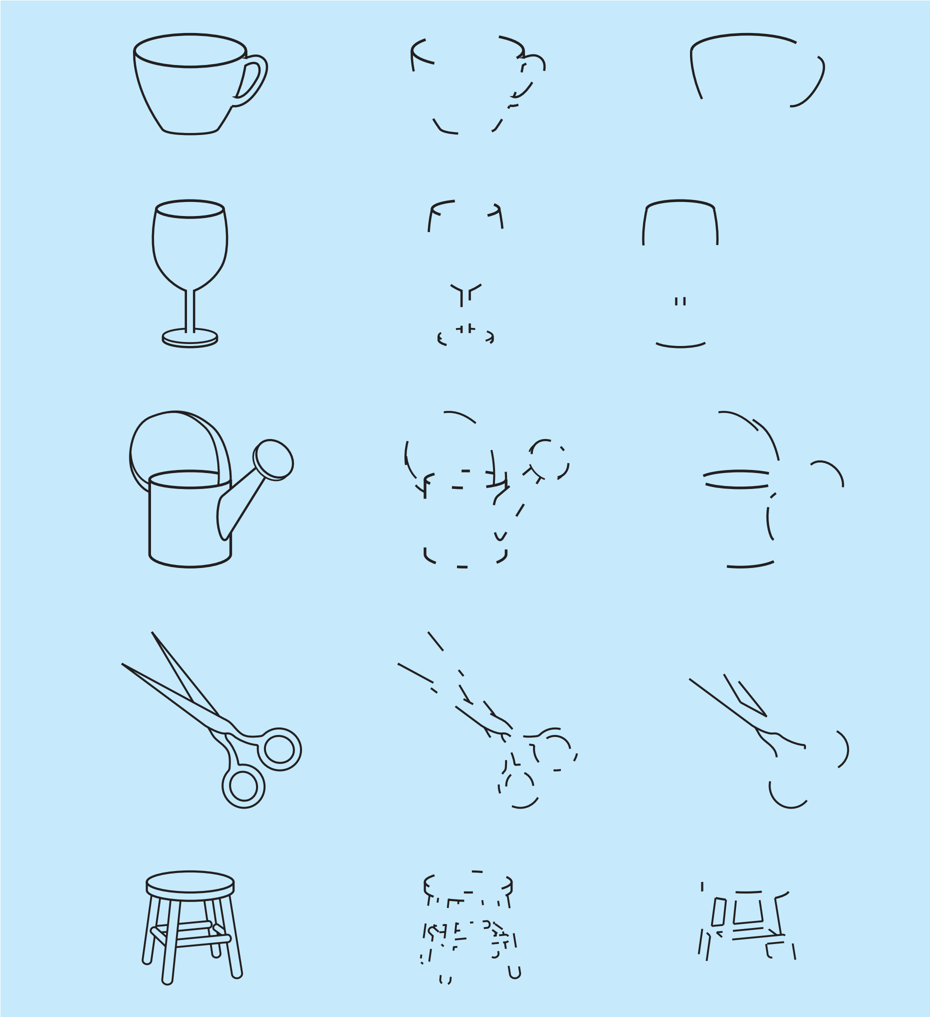
Biederman also showed that when people see incomplete drawings, such as those in Figure 3-13, they can identify the object if the intact parts of the picture include object vertexes—that is, segments that allow the identification of component geons—as in the degraded pictures in the middle column. However, when vertexes are deleted, as in the rightmost column, this destroys the perceiver's ability to recover the underlying geons and greatly reduces (almost to zero) the probability of correctly identifying the object. (Note: Not all perception researchers accept the notion of geons as fundamental units of object perception. Tarr and Bülthoff, 1995, present a complex but interesting competing proposal.)

Other research has provided additional evidence of featural processing in perception. For example, flashing letters on a computer screen for very brief intervals of time typically results in certain predictable errors. For example, people are much more likely to confuse a *G* with a *C* than with an *F*. Presumably this is because the letters *C* and *G* share many features: a curved line, an opening to the right. Eleanor Gibson (1969) has tabulated the features of capital letters for the Roman alphabet we use, as shown in Table 3-1.

Studies by Neisser (1963) confirmed that people use features to recognize letters. Neisser had participants perform a **visual search task** in which researchers presented them with arrays of letters, such as those shown in Figure 3-14. The researchers asked them to respond if they detected the presence of a particular target, such as the letter *Q* or the letter Z. Shown an array such as Figure 3-14(A), participants took much longer to find a Z than they did to find a *Q*; the reverse was true for arrays similar to Figure 3-14(B). The nontarget letters in array (A) all share features like straight and angular lines, whereas those

**FIGURE 3-13** ■ *Five stimulus objects used in the experiment on degraded objects. See text for explanation.*

**SOURCE:** Biederman (1987, pp. 122–123).



in array (B) share features such as roundness. Similarity between the target letter (Z or Q) and the nontarget letters can make the search much harder.

Similar findings have been reported for auditory perception of syllables that share many articulatory features. For example, *da* and *ta* are more likely to be confused than are two syllables that share fewer similarities, such as *da* and *sa* (Miller & Nicely, 1955). Examples of articulatory features (for consonants) include voicing, or vibration of the vocal cords (*b* is voiced, for example, but *p* is

## Table 3-1 Features of Capital Letters

| *Features* | A | E | F | H | I | L | T | K | M | N | V | W | X | Y | Z | B | C | D | G | J | O | P | R | Q | S | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Straight | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Horizontal | + | + | + | + | | + | + | | | | | | | | + | | | | + | | | | | | | |
| Vertical | | + | + | + | + | + | + | + | + | + | | | | + | | + | | + | | | | + | + | | | |
| Diagonal / | + | | | | | | | + | + | | + | + | + | + | + | | | | | | | | | | | |
| Diagonal \ | + | | | | | | | + | + | + | + | + | + | + | | | | | | | | | + | + | | |
| Curve | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Closed | | | | | | | | | | | | | | | | + | | + | | | + | + | + | + | | |
| Open V | | | | | | | | | | | | | | | | | | | | + | | | | | | + |
| Open H | | | | | | | | | | | | | | | | | + | | + | + | | | | | + | |
| Intersection | + | + | + | + | | | + | + | | | | | + | | | + | | | | | | + | + | + | | |
| Redundancy | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cyclic change | | + | | | | | | | + | | | + | | | | + | | | | | | | | | + | |
| Symmetry | + | + | | + | + | | + | + | + | | + | + | + | + | | + | + | + | | | + | | | | | + |
| Discontinuity | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vertical | + | | + | + | + | | + | + | + | + | | | | + | | | | | | | | + | + | | | |
| Horizontal | | + | + | | | + | + | | | | | | | | + | | | | | | | | | | | |

**Source:** E. J. Gibson (1969, p. 88).

**FIGURE 3-14** ■ *Visual search stimuli. Notice how long it takes to find a Z or a Q in (A) and (B).*

| | |
|---|---|
| E I M V W X | C D G O R U |
| X M Z W V I | R D Q O C G |
| V I E X W M | G R D C O U |
| W V X Q I E | D C U R Z G |
| (A) | (B) |

not); nasality, whether the air is directed into the nasal passages (*n*) or not (*l*); duration, how long the (consonant) sound lasts (compare *s* with *t*); and place of articulation, where in the mouth the sound is formed (compare *p* and *b*, formed in the front; *t* and *d*, formed in the middle; and *k* and *g*, formed in the back).

Selfridge (1959) developed a model for the perception of letters that was based on featural analysis. The model was called **Pandemonium,** for reasons that will soon become clear. It consists of a number of different kinds of "demons," which function basically as feature detectors. Demons at the bottom (first) level of processing scan the input, and demons at higher levels scan the output from lower-level demons. In response to what they find, the demons scream. The first kind of demons are image demons, which convert the proximal stimulus into representations, or internal depictions of information, that higher-level demons can assess. Each representation is scanned by several feature demons, each looking for a different particular feature (such as a curved or a vertical line). If a demon finds such a feature, that demon screams.

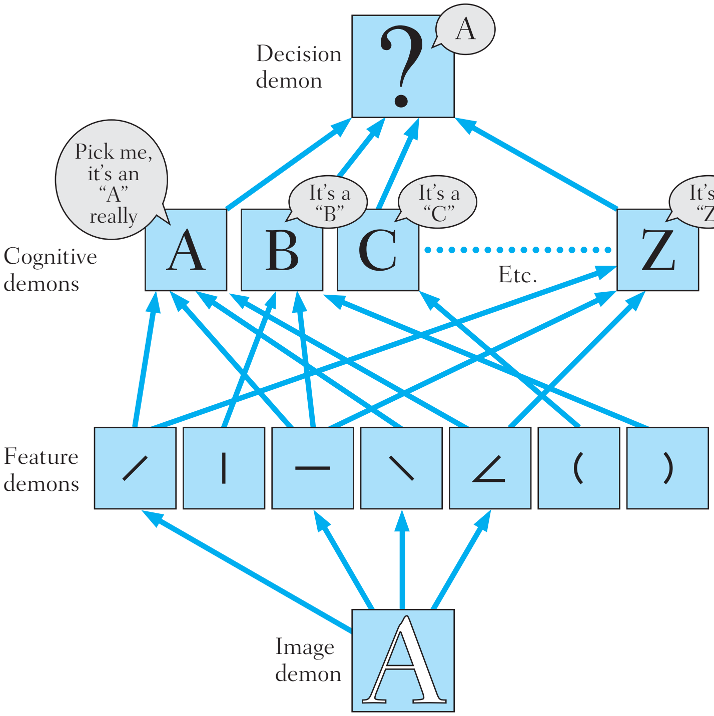
Feature demons communicate the level of confidence that the feature is present by screaming more softly or loudly. Letter demons cannot look at the stimulus itself but can only listen to the feature demons. The letter demons pay particular attention to the demons associated with their particular letter. The *A* demon, for instance, listens especially hard to the feature demons for "slanted line" and "vertical line." Letter demons scream when the output from the feature demons convinces them their letter is in the representation—again, more loudly or softly, depending on the level of confidence. A single decision demon listens to all this screaming and decides what letter is being presented.

Figure 3-15 illustrates the structure governing the screaming chaos of the demons. The Pandemonium model, named with a sense of humor, illustrates a number of important aspects of featural analysis. First, demons can scream more loudly or softly, depending on the clarity and quality of the input. This allows for the fact that real-life stimuli are often degraded or incomplete, yet objects and patterns can still be recognized. Second, feature demons can be linked to letter demons in such a way that more important features carry greater weight. This takes into account that some features matter more than others in pattern recognition.

Take the case of the letter *A*. In writing this letter, some people are sloppy about their slanted vertical lines (sometimes the lines are almost parallel), yet the *A* is still often recognizable. Without the horizontal line, however, the pattern seems to stop being an *A*. In the Pandemonium model, then, the letter demon for *A* would be more tightly connected to the horizontal-line feature demon than it would be to the slanted-line demons. Last, the weights of the various features can be changed over time, allowing for learning. Thus a demon model could learn to recognize my mother's handwritten *A*'s, even though she makes her capital *A*'s with no slanted lines, only two very curved

**FIGURE 3-15** ■ *A depiction of Selfridge's (1959) Pandemonium model.*

**SOURCE:** Klatzky (1980).



lines. With practice, this model could learn to read even my doctor's handwriting—something even I have trouble with!

Featural analysis models are not without problems, however. To begin with, there are at present no good definitions of what can be a feature and what cannot, except in very restricted domains, such as the perception of letters or the perception of line drawings of familiar objects. Consider the perception of a face. Are there general features for eyes, nose, mouth? Are there specific features for right nostril, left eyebrow, lower lip? Just how many features can there be? Do different kinds of objects have different sets of features? Consider a vertical line. Although this feature is no doubt important for perceiving the letter *A,* how does it relate to perceiving a real human face? A beach ball? A wave crashing on shore? If there are different sets of features for different objects, how does the perceiver know which ones to use to perceive an object (remember, this must be decided *before* the perceiver knows what the object is). If the same set of features applies to all objects, the list of possible features would appear huge. How does the perceiver perceive objects so fast, then?

By the way, we will encounter featural models again when we talk about concepts in Chapter 8. All the questions and concerns about featural models will appear there as well.

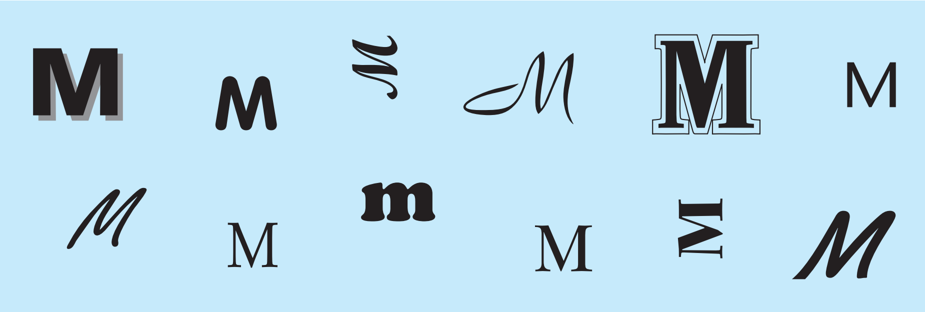
## Prototype Matching

Another kind of perceptual model, one that attempts to correct some of the shortcomings of both template-matching and featural analysis models, is known as *prototype matching*. Such models explain perception in terms of matching an input to a stored representation of information, as do template models. In this case, however, the stored representation, instead of being a whole pattern that must be matched exactly or closely (as in template-matching models), is a **prototype,** an idealized representation of some class of objects or events—the letter *M,* a cup, a VCR, a collie, and so forth.

You can think of a prototype as an idealization of the thing it represents. The prototypical dog, for instance, would be a depiction of a very, very typical dog—the "doggiest" dog you could think of or imagine. There may or may not be in existence any particular dog that looks exactly like the prototype. Figure 3-16 shows variations of the letter *M*. If your intuitions agree with those of most people I've shown this figure to, you'll judge the letters toward the center of the figure to be more prototypical.

Prototype-matching models describe perceptual processes as follows. When a sensory device registers a new stimulus, the device compares it with previously stored prototypes. An exact match is not required; in fact, only an approximate match is expected. Prototype-matching models thus allow for discrepancies between the input and the prototype, giving prototype models a lot more flexibility than template models. An object is "perceived" when a match is found.

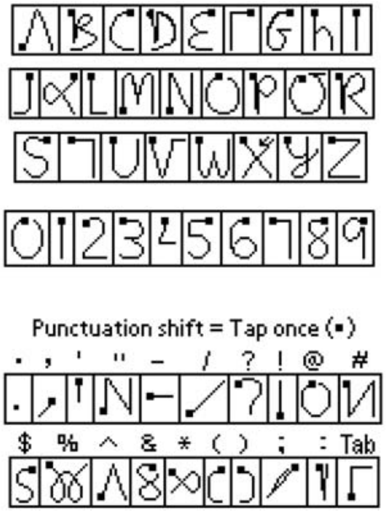
**FIGURE 3-16** ■ *Examples of the letter M.*



Many of you are familiar with Palm Pilots, handheld personal digital assistants (PDAs) that allow users to keep calendars, date books, address books, and so forth, all in a little box smaller than a deck of cards. Palm Pilots make use of prototype matching in their "graffiti writing system," depicted in Figure 3-17. Although people's handwriting differs (in size, amount of slant, steadiness of the lines drawn), the PDA evidently tries to make the best match of an input letter written by the user to one of the several letter or number prototypes, a subset of which is shown in Figure 3-17.

**FIGURE 3-17 ■** *Basic "Graffiti" characters from the Palm Pilot personal digital assistant.*

**SOURCE:** Available on the Web at http://www.palm.com/support/handbooks/m125_gsg_US.pdf and accessed on January 14, 2003.

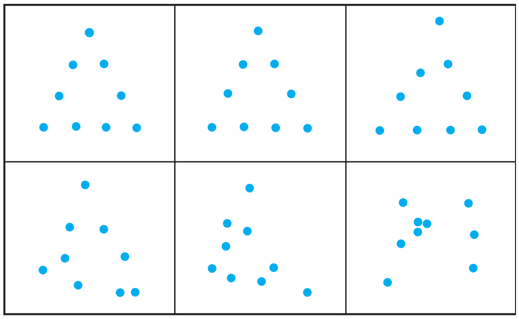


Prototype models differ from template and featural analysis models in that they do not require that an object contain any one specific feature or set of features to be recognized. Instead, the more features a particular object shares with a prototype, the higher the probability of a match. Moreover, prototype models take into account not only an object's features or parts but also the relationships among them.

Where, though, do prototypes come from? Posner and Keele (1968) demonstrated that people can form prototypes surprisingly quickly. These researchers created a series of dot patterns by arranging nine dots in a 30-by-30 grid to form a letter, a triangle, or a random pattern. The dots were then moved slightly to different positions in the grid (Posner, Goldsmith, & Welton, 1967). The original patterns were designated prototypes, and the others (which were really variations on the same basic patterns), distortions. Some examples are shown in Figure 3-18.

**FIGURE 3-18** ■ *Stimuli used by Posner and Keele (1968). The top left-hand box shows the prototype; other boxes show distortions.*

**SOURCE:** Posner et al. (1967, p. 30).



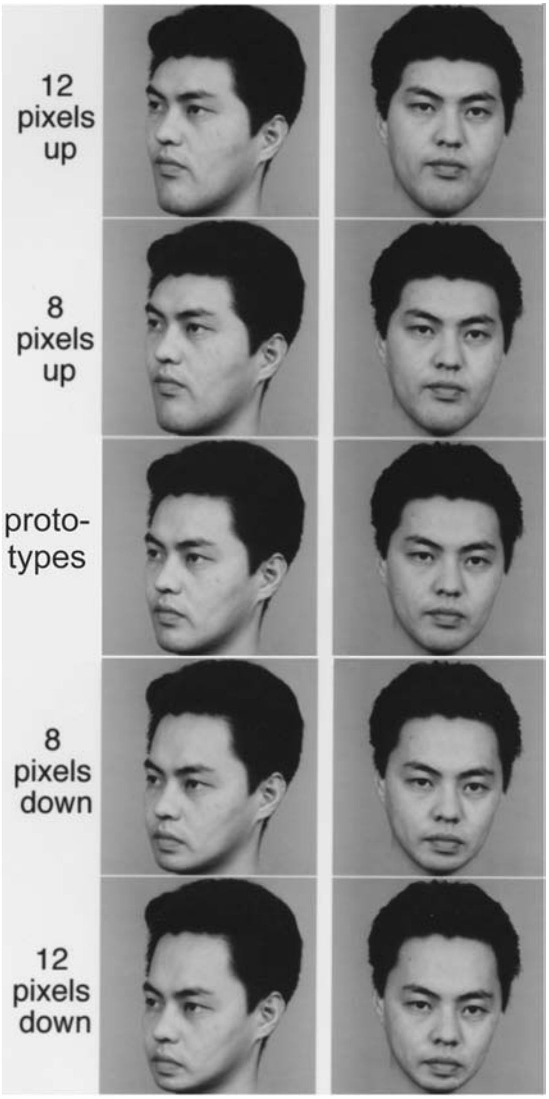
Participants viewed the various distortions but not the prototypes and were not told that the distortions were in fact distortions. Participants learned to classify the distortions into groups, based (unknown to the participants) on the original pattern from which the distortion was derived. After they could perform this classification without errors, participants were shown another series of dot patterns and asked to classify them in some way. The dot patterns shown in this part of the experiment were of three types: *old*—distortions participants had seen before; *new*—distortions participants had not previously encountered; and *prototypes,* also not previously seen. Participants correctly classified about 87% of the old stimuli, about 67% of new stimuli (still better than chance), and 85% of the prototypes.

Given that participants had never seen the prototypes before, their accuracy in classifying them is truly surprising. How can it be explained? Posner and Keele (1968) argued that during the initial classification task, people formed some sort of mental representation of each class of items. These representations might be mental images or pictures. Some participants described verbal rules for where dots were clustered and in what kinds of configurations. In any event, they used these representations when classifying new patterns.

This work lends credence to the idea that we form and use prototypes in our everyday perception. And the effects are not simply a function of artificial stimuli such as dot patterns. Cabeza, Bruce, Kato, and Oda (1999) showed a similar "prototype effect" with photographs of faces altered by displacing features (for example, eyebrows, eyes, nose, and mouth) up or down by a certain number of pixels. Figure 3-19 shows examples of the stimuli used. Reporting findings similar to those of Posner and Keele, Cabeza et al. found that research participants were more likely to "recognize" prototype faces they had never actually seen before than to recognize other, less prototypical new faces.

**FIGURE 3-19** ■ *Stimuli used in the studies by Cabeza et al. (1999, p. 141).*

**SOURCE:** From "The Prototype Effect in Face Recognition: Extensions and Limits," by Cabeza, R., Bruce, V., Kato, T., & Oda, M. (1999). *Memory and Cognition*, 27, p. 141. Reprinted by permission of the Psychonomic Society.



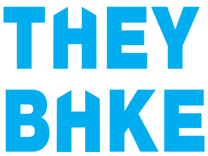
We will encounter the idea of prototypes again in Chapter 8, when we talk about concepts and categorization. The challenge, then, is to figure out when and how we form and use prototypes, what kind of processing is involved in matching, and how we know what prototypes to try to match inputs with. Note that many of these issues, including the number and origins of the stored representations, also arose for template-matching models.

## ■ TOP-DOWN PROCESSES

All bottom-up models share a number of problems in explaining how viewers "make meaning" of the stimuli they perceive. Two of the biggest problems are **context effects** and expectation effects.

Consider the display in Figure 3-20. Notice that the second character of both words is identical. Despite this, you probably read the two words as "they bake," perceiving the character in question unambiguously as an *h* the first time and then, milliseconds later, as an *a*. The context surrounding the character, *t* and *ey* the first time and *b* and *ke* the second time, obviously influenced what you perceived. The context in which a pattern or object appears apparently sets up certain expectations in the perceiver as to what objects will occur.

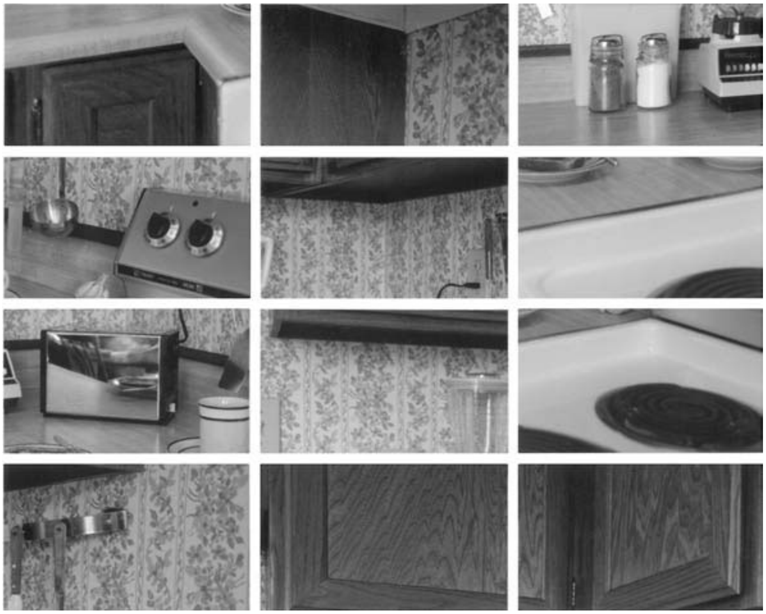
**FIGURE 3-20** ■ *An example of context effects in perception.*



Similar context effects have been demonstrated with perceivers looking to identify objects in real-world scenes: Both accuracy and the length of time needed to recognize objects vary with the context (Biederman, Glass, & Stacy, 1973; Palmer, 1975). For example, people recognize objects such as food or utensils faster in a scene depicting a kitchen than they do in the same scene jumbled up (see photos on the next page). These effects have led many psychologists to argue that any model of perception must incorporate context and expectations. We will look next at further demonstrations of the need to include top-down processes in theories and models of perception and pattern recognition.

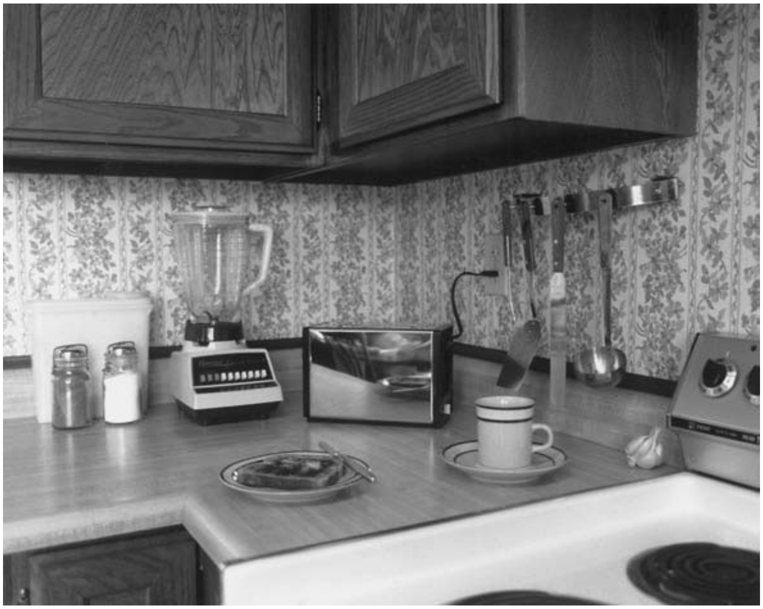
Top-down, or conceptually driven, processes, are those directed by expectations derived from context or past learning or both. If someone were to tell you a fly is in the room you are in right now, where would you look? Notice how this looking would change if you were to look for a spider or a cockroach. Your past experience with such creatures guides where you look first—whether to the walls, the floor, or the ceiling. You can think of the processing you do when you look for different insects as being top-down, in that your expectations and knowledge guide where you look.

Top-down processes have to interact with bottom-up processes, of course. Otherwise, you would never be able to perceive anything you were not expecting, and you would always perceive what you expected to perceive—clearly not



Nancy J. Ashmore

*The context surrounding an object can make perceiving it easy or hard. If we were to measure reaction time, we might find that it took people longer to recognize the toaster in the photo above than to recognize the same toaster in the photo below. The coherent kitchen scene sets up a context that aids perception of objects we expect to see in kitchens. The jumbled version of the scene destroys this context.*



Nancy J. Ashmore

true. A well-known example of a largely perceptual model incorporating both bottom-up and top-down processes is that of David Marr (1982). Marr's model is quite technical and mathematically elegant, and the interested reader is referred to his full description of it. For our purposes here, I offer a very brief sketch.

Marr proposed that perception proceeds in terms of several different, special-purpose computational mechanisms, such as a module to analyze color, another to analyze motion, and so on. Each operates autonomously, without regard to the input from or output to any other module, and without regard to real-world knowledge. Thus they are bottom-up processes.

Marr believed that visual perception proceeds by constructing three different mental representations, or sketches. The first, called a *primal sketch,* depicts areas of relative brightness and darkness in a two-dimensional image as well as localized geometric structure. This allows the viewer to detect boundaries between areas but not to "know" what the visual information "means." According to Gardner (1985),

> The primal sketch consists of a set of blobs oriented in various directions; these are reminiscent of the sorts of features discerned by Hubel and Wiesel's detectors—contrasts, spatial extent, general orientation at a local level. All these reductions and simplifications are conceived of as mental representations or symbolic depictions of the "raw information" transmitted by the light: Perception consists of a series of such simplified sketches *en route* to a more veridical view of the world. (p. 302)

Once a primal sketch is created, the viewer uses it to create a more complex representation, called a 2½-D (two-and-a-half-dimensional) sketch. Using cues such as shading, texture, edges, and others, the viewer derives information about what the surfaces are and how they are positioned in depth relative to the viewer's own vantage point at that moment.

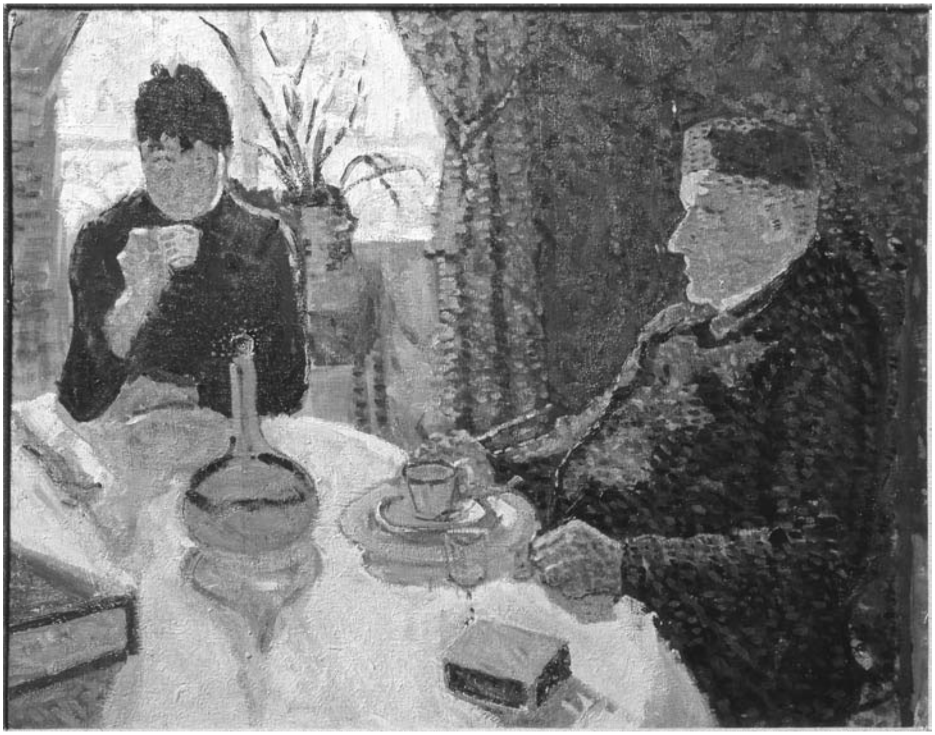
Marr believed that both the primal sketch and the 2½-D sketch rely almost exclusively on bottom-up processes. Information from real-world knowledge or specific expectations (that is, top-down knowledge) is incorporated when the viewer constructs the final, 3-D sketch of the visual scene. This sketch involves both recognition of what the objects are and understanding of the "meaning" of the visual scene.

Marr's theory is not the only one to incorporate top-down processes. Other perceptual phenomena in which these processes seem to operate are perceptual learning, change blindness, and the word superiority effect, each of which we will cover in turn.

But first, here's another connection between the psychology of perception and the world of fine arts: a look at the technique of impressionist painting, as depicted in Figure 3-21. The artist, Paul Signac, created a painting using small

**FIGURE 3-21** ■ *Paul Signac,* The Dining Room. *This painting is an example of top-down processing in viewing fine art.*

**SOURCE:** Bridgeman-Giraudon/Art Resource, NY.



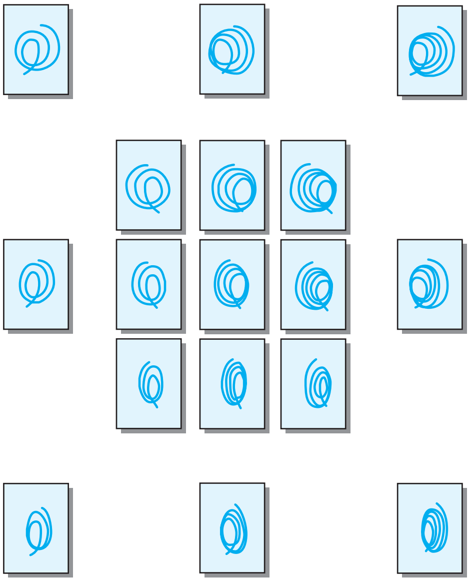
dabs of paint in a style known as *pointillism*. If you were to examine these dabs up close, they would not be very meaningful. However, when you view the whole painting from a reasonable distance, the little dabs somehow cohere into a meaningful interpretation: two patrons having coffee. Top-down processing allows this meaningful interpretation to emerge as we gaze at the painting!

## Perceptual Learning

That perception changes with practice has been well documented (E. J. Gibson, 1969); this phenomenon is called **perceptual learning.** A classic study by J. J. Gibson and E. J. Gibson (1955) illustrates this. Participants (both children and adults) were first shown the card in the very center of Figure 3-22, by itself, for about 5 seconds. Call this the original. Next, they were shown other cards,

**FIGURE 3-22** ■ *Stimuli used by Gibson and Gibson (1955).*

**SOURCE:** J. J. Gibson and E. J. Gibson (1955, p. 36).



randomly mixed in with which were four copies of the original. Their task was to identify any instances of the original in the deck. Participants received no feedback, but after seeing all the cards, they were shown the original card again for 5 seconds, then shown the full deck of cards in a new order. This procedure continued until each person correctly identified all and only the four copies of the original.

When Gibson and Gibson (1955) analyzed the errors participants made on this task, they found that the errors were not random. Rather, the number of errors seemed to depend most on the number of similarities a stimulus shared with the original. Participants were more likely to falsely recognize a stimulus that had the same number of coils and was oriented in the same direction as the original than to falsely recognize a stimulus that only had the same number of coils.

Over time, participants seemed to notice more about the figures, responding to features of the stimuli they apparently had not noticed earlier. This explanation accords with other, everyday examples of perceptual learning. Take wine tasting as an example. Experienced wine tasters will tell you that one needs much practice to really taste subtle differences. Novice wine tasters may be able to distinguish (by taste!) between a red and a white wine or even between a fruity and a dry white wine. Experts, by contrast, may be able to identify the

American, Kennel Club

*Perceptual learning is demonstrated at American Kennel Club–licensed dog shows. Here, the judge is examining all the Old English sheepdogs to determine which one best approaches an ideal standard. It takes years of practice to develop an eye to distinguish among dogs that, to the novice, might all look the same.*

vineyard that bottled a wine in a particular year. Novices simply miss this information—their taste buds may work exactly like those of experts, but some information seems to be overlooked.

What exactly is going on? Apparently, perceptually practiced individuals learn what aspects of the stimulus to attend to and try harder to consciously distinguish between different kinds of stimuli. With regard to top-down processes, a perceiver's experience appears to help guide what aspects of the stimulus to focus on, and also to facilitate the "pickup" of more information (Gauthier & Tarr, 1997a, 1997b; Gauthier, Williams, Tarr, & Tanaka, 1998).

## Change Blindness

A recent area of research in visual perception concerns a phenomenon known as **change blindness** (Rensink, 2002). This is the inability to detect changes to an object or scene, especially when given different views of that object or scene, and it illustrates the top-down nature of perception quite compellingly.

This phenomenon occurs outside the laboratory very frequently during the viewing of movies. Simons and Levin (1997) give the following examples: In the movie *Ace Ventura: When Nature Calls,* the pieces on a chess board disappear completely from one shot to the next. In *Goodfellas,* a child is playing with blocks that appear and disappear across shots. One inevitable consequence of film production is the need to shoot scenes out of order, and often to shoot components of the same scene at different times. As a result, unintentionally, many details within a scene may change from one view to the next. Although filmmakers go to considerable effort to eliminate such errors, almost every movie—in fact, almost every cut—has some continuity mistake. Yet, most of the time, people are blind to the changes (p. 264).

Simons and Levin (1997) provided a laboratory demonstration of this phenomenon. They showed undergraduate participants a short film clip depicting a young man sitting at a desk, then rising from the desk and answering a phone (see photos on next page). There was a camera cut during this sequence. Even when viewers were warned ahead of time there would be "continuity errors," they could not easily detect a fairly significant change: The actor first shown at the desk (photo A) is replaced by another actor, wearing different clothes (photo C)! One explanation for these findings is that the visual representations people make of a scene encode the "gist" of the scene (the basic meaning) but usually not the specific details. Thus changes to the scene that don't interrupt the "meaning" of the sequence don't call attention to themselves.

This implies that our visual percepts are not precise copies of our visual world. But is this simply a function of viewing motion pictures? Simons and Levin (1997), in a very clever study, conducted a "real-world" version of the laboratory study. They describe it as follows:

> Imagine that a person approaches you and asks for directions. Kindly, you oblige and begin describing the route. While you are talking, two people interrupt you rudely by carrying a door right between you and the person you were talking to. Surely you would notice if the person you were talking to was then replaced by a completely different person. (p. 266)

But in fact, only about 50% of their "participants" did. (The replacement was achieved by having the second "interviewer" carry the back half of the door up to the first interviewer and the participant; the first "interviewer" then changed places with him, in a scene reminiscent of a *Candid Camera* segment.) The change in person went undetected even though the two interviewers were of different heights and builds, had noticeably different voices, had different haircuts, and wore different clothing!

Interestingly, student participants were more likely to notice the change than were older participants (the study was conducted on the Cornell

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University campus). But when the two interviewers donned construction worker clothing, fewer than half the *students* noticed the change. Simons and Levin (1997) speculated that participants encoded the status (including age or profession) of the interviewer only for gist; students would pay more attention to the interviewers when they looked like other students, but less when the interviewers looked like construction workers.

The change blindness paradigm reinforces the idea that perception does seem driven by expectations about meaning. Instead of keeping track of every visual detail, we seem to represent the overall meaning of the scene. This may help prevent our perceptual system from being overwhelmed by the sheer amount of information available in any one glance or view.

Rensink (2002) has argued that to detect change, viewers must be focusing on the stimulus. Aginsky and Tarr (2002) further argue that some aspects of scene perception, such as presence and position of objects, automatically attract attention, whereas other aspects of a scene, such as color of objects, do not. We will turn to the topic of focused attention and a phenomenon known as inattentional blindness (Mack, 2003)—the inability to see what is directly in front of us unless we are paying attention—in Chapter 4.

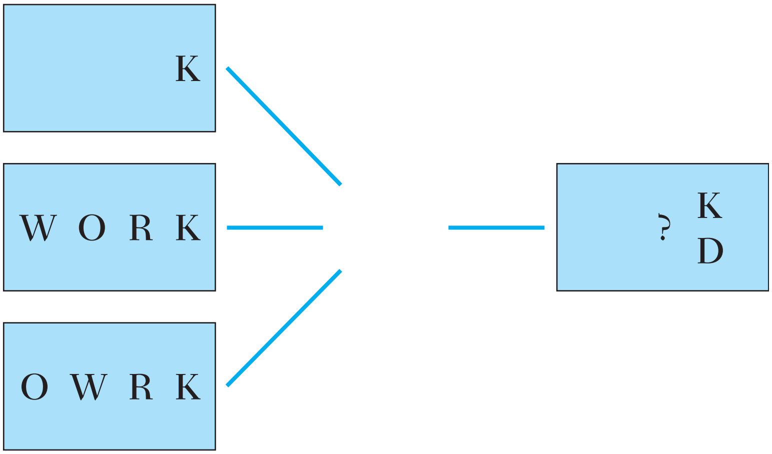
## The Word Superiority Effect

A study by Reicher (1969) illustrates another top-down phenomenon—the effects of context on perception in practiced perceivers. The basic task was simple: Participants were asked to identify which of two letters (for instance, *D* or *K*) was briefly presented on a screen. Later, they were presented with two alternatives for what the letter might have been, displayed directly above the letter's original position. Figure 3-23 depicts the experimental procedure.

The experiment contained an interesting twist, however. Sometimes a single letter was presented. At other times the letter appeared in the context of a word (such as *WORD* or *WORK;* notice that either *D* or *K* forms a common English word in combination with the same three letters). At still other times, the letter was presented with three other letters in a combination that did not form a word (*OWRD* or *OWRK,* for instance). In each case, the stimuli were then masked, and the participant was asked merely to say which letter, *D* or *K,* had been presented.

**FIGURE 3-23** ■ *Stimulus displays and procedures used by Reicher (1969).*

**SOURCE:** Reicher (1969, p. 277).



Surprisingly, participants could much more accurately identify letters presented in the context of words than the same letters presented alone or in the context of nonwords. This result, called the **word superiority effect** or the *word advantage,* has been replicated several times (Massaro, 1979). Letters are apparently easier to perceive in a familiar context (a word) than in an unfamiliar context or in no context at all. Theoretical explanations of this effect have been debated (Massaro, 1979; Papp, Newsome, McDonald, & Schvaneveldt, 1982). Not clear, for instance, is whether people detect more features in the letter when it occurs in a word or whether people make inferences about—guess at—the letter that would best complete the word. The point for our present purposes is that, once again, context and perceptual experience (for instance, at reading words) influence even as straightforward a task as perceiving a single letter. This insight has led to detailed models of letter perception that incorporate context-guided—that is, top-down—processes with bottom-up processes such as feature detection (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982).

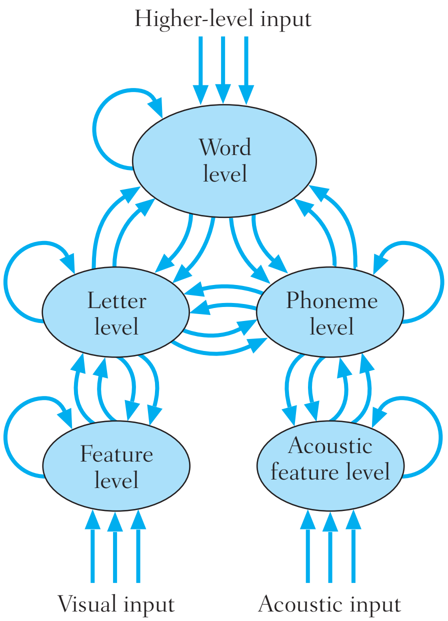
Interestingly, however, letter detection seems to operate very differently in a different context. When readers are asked to read a written text and cross out all the occurrences of a certain letter (say, *f*'s), they are very likely to miss the *f* in words like *of* or *for*, but to catch the *f*'s in words like *function* or *future,* a phenomenon known as the missing letter effect (Greenberg, Healy, Koriat, & Kreiner, 2004). Presumably, as readers read connected text, they quickly divide the words into content words (which carry meaning) and function words (which structure the content words); they focus their attention more on the moderately familiar content words and thus are likely to miss the letters in the highly familiar function words. We will explore this idea more fully in Chapter 10 when we discuss text processing. The point for now is that the ability to detect letters is enhanced by word familiarity when words appear in isolation, but inhibited by increased familiarity or role when a word appears in real text.

## A Connectionist Model of Word Perception

One of the detailed models is a connectionist model of letter and word perception, presented by McClelland and Rumelhart (1981). Figure 3-24 illustrates some of the processing levels the model assumes. Note that the model assumes that input—whether written (visual), spoken (acoustic), or of a higher level, such as arising from the context or the observer's expectations—is processed at several different levels, whether in terms of features, letters, phonemes (sounds), or words. Notice, too, the many arrows in the diagram, indicating the assumption that the different levels of processing feed into one another. Each level of processing is assumed to form a representation of the

**FIGURE 3-24** ■ *McClelland and Rumelhart's (1981) model of letter perception.*

**SOURCE:** McClelland and Rumelhart (1981, p. 378).



information at a different level of abstraction, with features considered less abstract than letters, and letters less abstract than words.

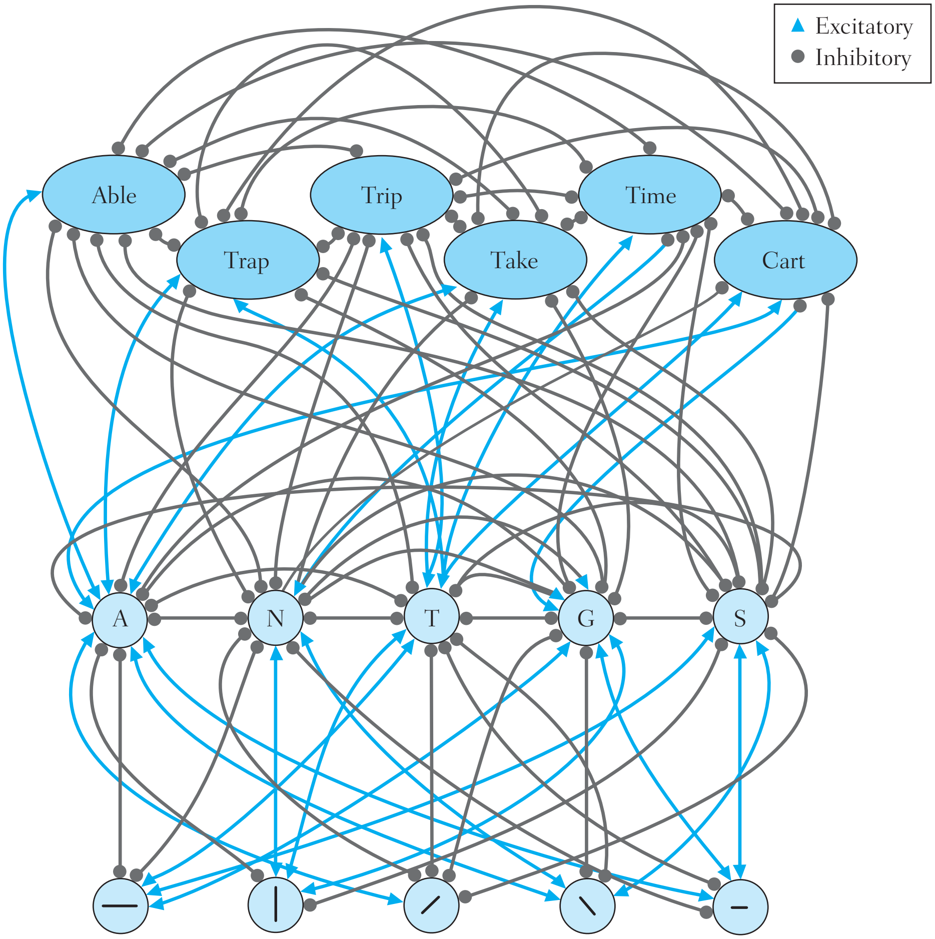
The model is presented in more detail in Figure 3-25. Each circle and oval in this figure depicts a node of processing in the model. The model assumes a different node for each distinct word, letter, and feature. Nodes have a certain level of activity at any given point in time. When a node reaches a given level of activity, we can say that its associated feature, letter, or word is perceived.

Note all the lines between nodes. These represent connections, which can be either excitatory or inhibitory. When an excitatory connection links two nodes, the two nodes suggest each other. Consider the nodes for the word *TRAP* and the letter *T,* for example. Imagine seeing a stimulus such as __*RAP* in a crossword puzzle in a family newspaper: four blanks, the last three of which are filled in with *R, A,* and *P*. Wouldn't this suggest the word *TRAP* to you? If so, a connectionist would say your node for *TRAP* had been activated.

Once a node is activated, that activation spreads along that node's excitatory connections to other nodes. If the *TRAP* node has an excitatory connection to the *T* node, then the *T* node will become more active when the *TRAP* node becomes more active, and vice versa. Excitatory connections are represented in Figure 3-25 by arrows ending with points. The lines ending in dots in Figure 3-25 indicate inhibitory connections, as in the line between the *TRAP*

**FIGURE 3-25** ■ *Nodes and connections in McClelland and Rumelhart's (1981) model of word perception.*

**SOURCE:** McClelland and Rumelhart (1981, p. 380).



node and the *ABLE* node. Thus if the *TRAP* node is active, the *ABLE* node becomes less active. If you perceive the word *TRAP,* you are less likely to perceive the word *ABLE* at the same instant. The assumption is that you can perceive only one word at any given instant.

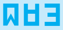
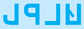
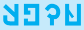
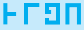
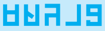
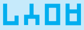
More could be said about this model, but our focus here is on how a connectionist model can be used to explain the word superiority effect. Why might a letter be easier to perceive in the context of a word? According to this model, perception of a word—that is, activation of the relevant node for the word—also activates the nodes corresponding to all the letters within the word, thereby facilitating their perception. Without the word context, the node for the individual letter is less active, so perception of the letter takes longer.

## A Neuroscientific Perspective on Word Perception

A very interesting study making use of PET technology also bears on the perception of words. Petersen, Fox, Snyder, and Raichle (1990) presented eight adults with four different kinds of stimuli: true English words; pseudowords, which follow the pronunciation rules of English but happen not to be real words; letter strings that contain no vowels and hence are not pronounceable; and *false fonts* that use the features of letters of the alphabet, but never in the usual combinations. Examples of the stimuli used are shown in Figure 3-26.

**FIGURE 3-26** ■ *Example of stimuli used in the PET scan study of processing words. See text for explanation.*

**SOURCE:** Posner and Raichle (1994, p. 79).

| Words | Pseudowords | Letter Strings | False Fonts |
|---|---|---|---|
| ANT | GEEL | VSFFHT |  |
| RAZOR | IOB | TBBL |  |
| DUST | RELD | TSTFS |  |
| FURNACE | BLERCE | JBTT |  |
| MOTHER | CHELDINABE | STB |  |
| FARM | ALDOBER | FFPW |  |

Words and pseudowords produced different PET scans from those produced when participants saw letter strings or false fonts. That is, different brain areas were active when the different types of stimuli were shown. With all four types of stimuli, the PET scan showed activity in the visual cortexes of both hemispheres. With both pseudowords and real words, however, the PET scans showed greater activity in the left than the right hemisphere and in regions outside the primary visual cortex (see Figure 3-27). The authors argued that this part of the brain is the part involved in semantic processing—that is, processing of stimuli for meaning. This study lays the groundwork for further work in creating a detailed "map" of the brain to understand further how various cognitive processes are realized neurologically.

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## DIRECT PERCEPTION

The models of perception we have looked at so far all share a common assumption. Recall that, as shown in Figure 3-1, the perceiver must acquire information about a distal stimulus, presumably by interpreting the proximal stimuli (retinal images, in the case of visual perception). The common assumption underlying the models of perception we have examined (especially the top-down models) is that the perceiver does something to the proximal stimulus. Presumably, because the proximal stimulus doesn't contain all the information we need to identify the object (for instance, because retinal images are two-dimensional instead of three-dimensional or because objects might be blurred or blocked by other objects), we, as observers, must use our knowledge to fill in gaps.

To put it more simply, these models describe the act of perception as the construction of mental representations of objects. From the information we are perceiving, we somehow construct a depiction that may or may not physically resemble the object or event being perceived but that our cognitive and physiological processes can recognize as corresponding to the information perceived. We use both the information in the proximal stimulus and information from our long-term memory to construct these mental representations.

This idea is called the **constructivist approach to perception** (Hochberg, 1978), for obvious reasons. It describes people as adding to and distorting the information in the proximal stimulus to obtain a percept, a meaningful interpretation of incoming information. People are not seen as passively taking in all the available information; instead, they are seen as active selectors, integrators, and constructors of information.

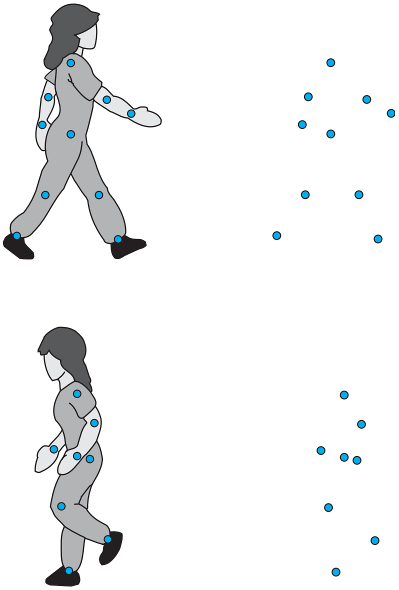
James Gibson and his followers (J. Gibson, 1979; Michaels & Carello, 1981) adopted an opposite stance. Gibson rejected the idea that perceivers construct mental representations from memories of past encounters with similar objects and events. Instead, Gibson believed that the perceiver does very little work, mainly because the world offers so much information, leaving little need to construct representations and draw inferences. He proposed that perception consists of the direct acquisition of information from the environment.

According to this view, called **direct perception,** the light hitting the retina contains highly organized information that requires little or no interpretation. In the world we live in, certain aspects of stimuli remain invariant (or unchanging), despite changes over time or in our physical relationship to them. You may already be familiar with the idea of invariance. For example, consider a melody played on a piano in the key of C. Now, imagine that same melody transposed to the key of G. Although all the individual notes in the melody have been changed, the melody is still easily recognized. If sufficient time lapses between renditions, many listeners may not even recognize the key change. The elements (notes) have changed, but the relationships between the notes have remained constant, or invariant.

A visual example of perceptual invariance was demonstrated in a study by Johansson (1973). Researchers attached lightbulbs to the shoulders, elbows, wrists, hips, knees, and ankles of a model who wore black clothing and was photographed in the dark so only the lights could be seen (see Figure 3-28). Participants who were shown a still photograph of the model reported seeing only a random group of lights. Participants who saw a videotape of the model engaged in familiar activities—walking, dancing, climbing, and so forth—immediately recognized a person carrying out a particular activity. Later work (Koslowski & Cutting, 1977) even showed that observers could distinguish between a male and a female model, just by the movement of the lights! Apparently, the motion of the lightbulbs relative to one another gave an observer enough information to perceive a human being in motion. Note that in this example the observer did not see the person's shape or any individual features such as hair, eyes, hands, or feet. If a human form can be quickly recognized under these limited viewing conditions, imagine how much more information is available under normal circumstances.

**FIGURE 3-28** ■ *A depiction of Johansson's (1973) experimental stimuli.*

**SOURCE:** Johansson (1973, p. 202).



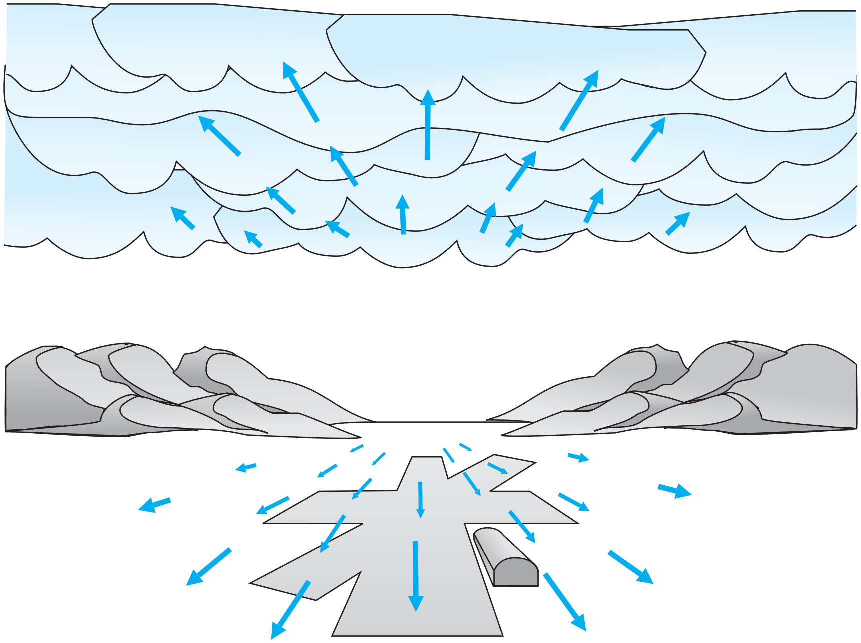
J. J. Gibson (1950) became convinced that patterns of motion provide a great deal of information to the perceiver. His work with selecting and training pilots in World War II led him to thinking about the information available to pilots as they landed their planes. He developed the idea of optic flow, depicted in Figure 3-29 as the visual array presented to a pilot approaching a runway for landing. The arrows represent perceived movement—that is, the apparent movement of the ground, clouds, and other objects relative to the pilot. There is a texture to this motion: Nearer things appear to move faster than things farther away, and the direction in which an object seems to move depends on the angle of the plane's movement in relation to it. The pilot can use all this information to navigate the plane to the runway.

Turvey, Shaw, Reed, and Mace (1981) argued that whereas non-Gibsonian models of perception try to explain how people come to perceptual beliefs and judgments, Gibson tried to explain how people "adjust," physically and otherwise, to the environment. For Gibson, the central question of perception is not how we look at and interpret a stimulus array but rather how we see and navigate among real things in the world. Why don't we normally walk into walls, for instance, or flinch from a perceived impending collision with walls?

An important idea in Gibson's theory is that the information available to an organism exists not merely in the environment but in an animal–environment

**FIGURE 3-29** ■ *A depiction of optic flow.*

**SOURCE:** J. J. Gibson (1950, p. 121).



ecosystem (Michaels & Carello, 1981). As animals move about, they continuously experience their environments. Different biological organisms have different perceptual experiences because (among other things) different organisms have different environments, different relationships to their environments, or both. Organisms directly perceive not only shapes and whole objects but also each object's **affordances**—the "acts or behaviors permitted by objects, places, and events" (Michaels & Carello, 1981, p. 42)—in other words, the things offered by the environment to the organism. Thus for human beings, chairs afford sitting, a handle or knob affords grasping, a glass window affords looking through. J. J. Gibson (1979) claimed that affordances of an object are also directly perceived; that is, we "see" that a chair is for sitting just as easily as we "see" that a chair is 2 feet away or made of wood.

According to Gibson, then, we avoid crashing into walls and closed doors because such surfaces do *not* afford passing through, and we perceive this as we move toward them. We sit on chairs or tables or floors but not on top of bodies of water, because the former afford sitting, whereas the latter do not. By virtue of our activity with and around different objects, we pick up on these affordances and act accordingly. Perception and action, for Gibson, are intimately bound.

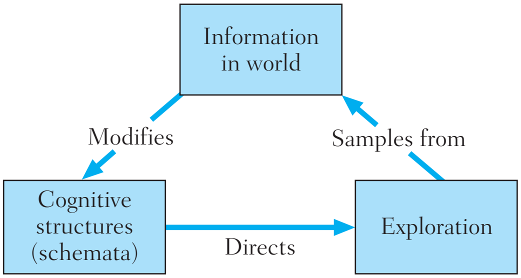
Gibsonian theory has been both staunchly admired and sharply criticized. Fodor and Pylyshyn (1981), for example, argued that Gibson's proposals, while intriguing, are not well defined. Without sharp definitions of what an affordance is, they argued, the theory is not helpful in explaining perception. They charged that Gibson failed to specify just what kinds of things are invariant and what kinds are not. Without this specification, the following kinds of circular explanations can result: How do people perceive that something is a shoe? There is a certain (invariant) property that all and only shoes have—namely, the property of being a shoe. Perceiving that something is a shoe consists in the pickup of this property (Fodor & Pylyshyn, 1981, p. 142).

How much of a challenge do Gibsonian views pose to constructivist views of perception? Put another way, can constructivist and direct perception views be reconciled? Cognitive psychologists have not yet resolved the issue. One proposal tried to incorporate aspects of both approaches. Neisser (1976) described what he called the *perceptual cycle,* depicted in Figure 3-30. In this model, cognitive structures called *schemata* (singular: **schema**), derived from the knowledge base and containing expectations derived from context, guide the perceiver to explore the environment in particular ways. The environment, in turn, supplies certain information that confirms some expectations but not others. This helps the perceiver modify her expectations and, perhaps, bring other schemata to bear in the next cycle of perception. We will discuss the idea of schemata in much greater depth in Chapter 7. For the present, note that Neisser's model again assumes an active perceiver.

However the debate between supporters and critics of Gibson is resolved, he has reminded everyone in cognitive psychology of the need to pay attention to the way cognition operates outside the laboratory and of the relationship between the way information is processed and the goals and needs of the organism doing the processing. We will return to these themes throughout the book.

**FIGURE 3-30** ■ *Neisser's (1976) perceptual cycle.*

**SOURCE:** Adapted from Neisser (1976, p. 21).



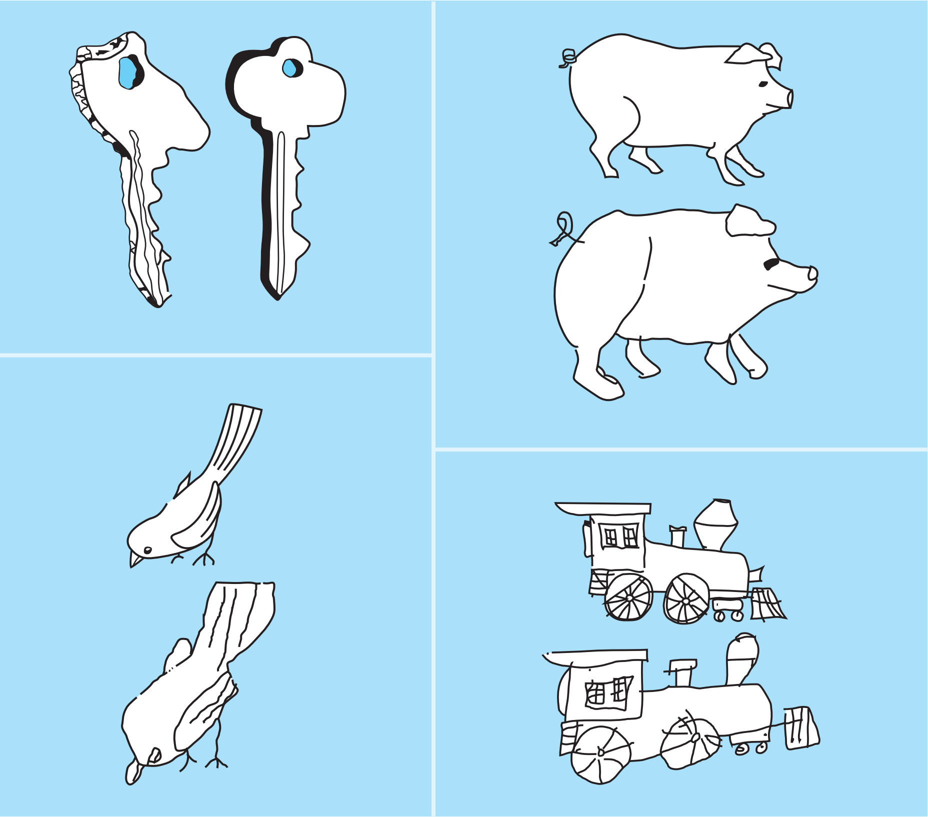
## DISRUPTIONS OF PERCEPTION: VISUAL AGNOSIAS

Earlier, I said that perception is a process by which we attach meaning to sensory information we receive. That definition distinguishes between sensation (for example, vision, hearing, olfaction), or the receiving of sensory information, and another process, perception, which makes sense of that sensory information.

One of the best illustrations that sensation and perception are distinct processes comes from cognitive neuropsychological work on **visual agnosias,** impairments in the ability to *interpret* (although seeing) visual information (Banich, 1997). For example, consider Figure 3-31, from a case study reported by Rubens and Benson (1971). This figure shows drawings shown to a patient

**FIGURE 3-31** ■ *Four drawings and the copies made by the associative agnosic patient studied by Rubens and Benson (1971). Despite being able to see the drawings well enough to copy them, the patient was unable to recognize them.*

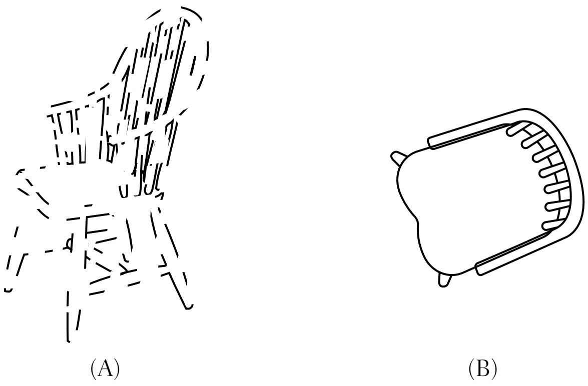
**SOURCE:** Rubens and Benson (1971, p. 310).



and his reproduction of them. As you can see, this patient saw the drawings clearly, and his renditions of each drawing reproduce several details. But this same patient could not correctly name *any* of the objects he saw and drew, saying of the pig that it "could be a dog or any other animal," and of the bird that it "could be a beech stump" (p. 310). Patients suffering from visual agnosia do not simply have a language problem, because they are similarly unable to use nonverbal means of recognizing familiar objects (such as pantomiming their usual uses). Nor do they have a memory problem, because they can tell you what a pig or a key is. Instead, the problem seems to lie in understanding what the visual pattern or object presented to them is (Farah, 1990). The deficit seems modality specific: Patients with visual agnosia can't recognize objects by sight but may be able to recognize them by sound, or touch, or smell. Put in our earlier terms, the problem seems to lie in creating a percept from the proximal stimulus.

Researchers classify visual agnosias into different types. The first is called *apperceptive agnosia.* Patients with this disorder seem able to process a very limited amount of visual information. They can see the *contours,* or outlines, of a drawing or object but have a very difficult time matching one object to another or categorizing objects. Some cannot name objects at all, and at least one has been reported to be unable to distinguish printed *X*'s from *O*'s (Banich, 1997). Other patients can do this much processing but have trouble recognizing line drawings when some parts of the outlines are missing, such as the drawing of a chair shown in Figure 3-32(A), or recognizing objects shown in an unusual orientation, as in the drawing of the chair as viewed from the top in Figure 3-32(B).

**FIGURE 3-32** ■ *Examples of how contour information influences recognition in persons with apperceptive agnosia. (A) Patients with apperceptive agnosia have difficulty recognizing this object as a chair because they cannot interpolate the missing contours. (B) Patients with apperceptive agnosia would have difficulty recognizing the chair when it is viewed from this unusual angle.*



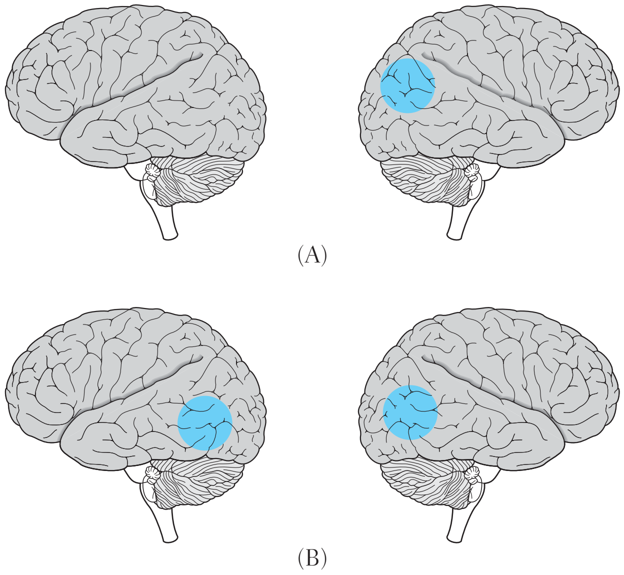
A second kind of agnosia is called *associative agnosia*. Patients with this deficit *can* match objects or drawings and copy drawings, but they tend to do so very slowly and very, very carefully, almost point by point (Banich, 1997), instead of using the more typical technique of drawing the big features first and then filling in details. Associative agnosic patients may also become distracted by small details, such as an extra dot or stray line on a drawing. Associative agnosic patients cannot readily name the objects they have seen and drawn.

The two different types of visual agnosia seem associated with injury to two different areas of the brain. Apperceptive agnosia is typically associated with one hemisphere, or one side of the brain, the right, as shown in Figure 3-33(A). Associative agnosia is correlated with *bilateral* damage to a particular region of the brain (that is, in both cerebral hemispheres), as shown in Figure 3-33(B).

Yet another kind of visual agnosia, called **prosopagnosia,** is a very specific visual agnosia for faces (Farah, 1990). Prosopagnosic patients, who typically suffer from damage to a particular region in the right hemisphere (possibly with some left hemisphere involvement as well) may have intact object recognition abilities but may be unable to recognize faces of their family members or

**FIGURE 3-33** ■ *The regions of the brain typically damaged in apperceptive and associative agnosia. (A) In apperceptive agnosia, damage is usually restricted to posterior sections of the right hemisphere. (B) In associative agnosia, the damage tends to be bilateral at the occipitotemporal border. Relative to the lesion in apperceptive agnosia, the typical lesion in associative agnosia is more ventral.*

**SOURCE:** Reprinted with permission from Banich (1997, p. 175).



political leaders or even photographs of their own faces. They can see details—a nose, an eyebrow, a mole—but can't seem to put the visual details together into a coherent percept. A book by Oliver Sacks (1985) gives vivid details of cases of prosopagnosia.

Visual agnosias are not the only kind of neurological deficit relevant to the cognitive processes of perception and pattern recognition. Another well-known impairment, known as *unilateral neglect* (sometimes also called hemineglect), comes about as a result of damage to the parietal cortex and causes the patient to virtually ignore stimuli on the opposite side (Mozer, 2002). For example, patients with right-hemisphere parietal damage may fail to wash the left side of their body, comb the hair on the left side of their face, or respond to stimuli that originate on the left side of the body.

This very brief review of neurological deficits in perception shows there is more to perception than simply receiving information. Seeing, whether or not it is believing, is certainly not perceiving!

## SUMMARY

Researchers have proposed a number of distinct approaches to the study of perception. Despite differences in the theoretical assumptions made and the experimental methods used in each approach, researchers agree on at least two general principles, shown as points 1 and 2 in the following list.

1. Perception is more than the sum of static, individual sensory inputs. Perception clearly involves some integration and, perhaps, some interpretation of the sensations we receive. Perception is *not* a matter of simply taking in information from the world and creating from it a duplicate internal representation.
2. Perception sometimes involves "seeing" things that are not there (as in the case of subjective contours) or distorting things that are (as in the case of other context effects). Perception involves both bottom-up processes, which combine small bits of information obtained from the environment into larger pieces, and top-down processes, which are guided by the perceiver's expectations and theories about what the stimulus is.
3. One important perceptual task is the segregation of the figure from the background. Gestalt psychologists offered many principles of how we accomplish this task, including the principles of proximity, similarity, good continuation, closure, and common fate. All of them follow the law of Prägnanz, which states that of all the possible interpretations a perceiver could make of a stimulus, he or she will select the one that yields the simplest, most stable form.
4. Various bottom-up models of perception include template matching, which holds that patterns are recognized when perceivers match them to stored mental representations; prototype matching, which posits that the stored mental

representations are not exact copies of stimuli but rather idealizations; and featural analysis, which holds that we first recognize features or components of patterns and objects and then put information about those components together to form an integrated interpretation.

5. Top-down models of perception incorporate perceivers' expectations into the model of how we interpret sensory information. Recent work on change blindness suggests that people process everyday visual information only to the level of gist, glossing over many details. Research on the word superiority effect demonstrates that context changes our perception of stimuli.
6. The connectionist model of letter perception illustrates just how complex the task of recognizing single letters (all typewritten in a single, simple font) can be.
7. Perception involves a great deal of activity on the part of the perceiver. We do more than simply record the visual world around us; we are not cameras. In both the constructivist and the direct-perception approaches to perception, perception is assumed to be the result of activity, either mental or physical. We navigate the world, gathering information as we go, seeking more information about objects of interest as a matter of course. Any theory of perception must ultimately take into account our own activity in our everyday perception.
8. Disruptions of perception (as in visual agnosias, including prosopagnosia) involve not understanding or recognizing what is seen. Apperceptive agnosias involve intact recognition of contours but an inability to recognize what the object is. Associative agnosics can (sometimes, slowly) recognize the identity of objects but focus intently on small details. Prosopagnosia is an inability to recognize faces, either of relatives, famous people, or even one's own reflection or photograph.

The topic of perception is fundamental to the study of cognition and relates to many topics discussed later in this book. Perception relates directly to attention, for example—the subject of Chapter 4—in that often our level of attention affects whether or not we perceive and remember something. When we talk about imagery, in Chapter 9, we will look again at how people process visual information. Moreover, what is perceived often constrains what else the perceiver can do with the information, in terms of recording and storing it, thinking about it, and drawing inferences from it. We will thus continue to encounter perceptual issues in the chapters ahead.

## REVIEW QUESTIONS

1. Describe the differences in assumptions about perception made by researchers working in (a) the traditional information-processing paradigm, (b) the connectionist paradigm, and (c) the Gibsonian ecological paradigm.

2. Describe two of the Gestalt laws of perceptual organization, illustrating each with a specific example.
3. Distinguish between bottom-up and top-down perceptual processes.
4. In what ways are featural analysis and prototype-matching models an improvement over template-matching models? In what ways are they not?
5. Evaluate the fit between Gestalt theories of perceptual organization and Biederman's geon theory.
6. Describe some real-life examples of context effects in perception.
7. Consider McClelland and Rumelhart's connectionist model of letter perception. How might a Gestalt psychologist regard this model, and what would he or she see as the model's strengths and weaknesses? How might a cognitive neuropsychologist regard this model, and what would he or she see as its strengths and weaknesses?
8. Discuss the following: "Part of the reason that J. J. Gibson's supporters and detractors have such spirited debates is that they are talking past each other. Gibson doesn't just present a different model of perception—he redefines what the task of perception is."
9. What do the different visual agnosias tell us about perception? (Hard: What are the limitations, both theoretical and empirical, of using case studies of brain-damaged individuals to inform theories of "normal" cognitive functions?)

## KEY TERMS

affordance
bottom-up process
change blindness
constructivist approach to perception
context effects
direct perception
distal stimulus
feature
form perception
geon
Gestalt principles of perceptual organization
Pandemonium model
pattern recognition
percept
perception
perceptual learning
phoneme
prosopagnosia
prototype
proximal stimulus
retina
retinal image
schema
size constancy
subjective contours
template
top-down process
visual agnosia
visual search task
word superiority effect

## CogLab DEMONSTRATIONS

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

If you have access to CogLab, a web-based set of demonstrations in cognitive psychology, you may want to try the **Apparent Motion** demonstration, which will give you some experience of your own perception being at odds with what is actually presented in the distal stimulus. The **Word Superiority** demonstration presents an experiment quite like the one described in the text, so you can experience the phenomenon firsthand.

## WEB RESOURCES

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

## CHAPTER

## 4

# Paying Attention

**Selective Attention**
- Filter Theory
- Attenuation Theory
- Late-Selection Theory
- Attention, Capacity, and Mental Effort
- Schema Theory
- Inattentional Blindness

**Neuroscientific Studies of Attention**
- Networks of Visual Attention
- Event-Related Potentials and Selective Attention

**Automaticity and the Effects of Practice**
- The Stroop Task
- Automatic Versus Attentional (Controlled) Processing
- Feature Integration Theory
- Attentional Capture

**Divided Attention**
- Dual-Task Performance
- The Attention Hypothesis of Automatization
- The Psychological Refractory Period (PRP)
- Divided Attention Outside the Laboratory: Cell Phone Usage While Driving

Consider the task of driving a car. Besides involving many physical skills—such as steering, braking, and shifting if you're driving a car with a manual transmission—driving also involves many cognitive processes. Perception is obviously one of them: You need to quickly recognize relevant objects, such as stop signs, pedestrians, or oncoming cars. Driving also requires mental effort or concentration—what cognitive psychologists call attention. The amount of attention required at any given time depends partly on the complexity of the situation around you: Driving on wide side streets with no traffic is usually easier than driving during rush hour on crowded freeways. Your level of concentration also depends on your level of expertise at driving (Crundall, Underwood, & Chapman, 2002).

Recall your first driving experiences. Most people behind the wheel of a car for the first time wear a look of extreme concentration. Gripping the wheel tightly, eyes darting at the street or parking lot ahead, the novice driver has great difficulty carrying on a conversation, tuning the car radio to a favorite station, or eating a hamburger. Six months later, given both enough driving experience and normal conditions, the same driver may well be able to converse, fiddle with knobs, eat, and drive, all at the same time.

Cognitive psychologists studying attention are concerned primarily with cognitive resources and their limitations. At any given time, they believe, people have only a certain amount of mental energy to devote to all the possible tasks and all the incoming information confronting them. If they devote some portion of those resources to one task, less is available for others. The more complex and unfamiliar the task, the more mental resources must be allocated to that task to perform it successfully.

Consider again the example of driving. The novice driver faces a complicated task indeed. She must learn to operate many mechanisms: gas pedal, brake, gear shift, clutch, lights, high-beam switch, turn signal, and so on. At the same time, while the car is in motion, the driver must scan ahead to see what is in front of the car (the road, trees, brick walls, and the like) and should also occasionally check the speedometer and the rearview mirrors. That's a lot to master, and, not surprisingly, it presents such a complicated set of demands that few cognitive resources are left for other kinds of cognitive tasks—talking, tuning the radio, fishing out a stick of gum from a purse or backpack, applying makeup.

However, with practice, the driver knows exactly where all the mechanisms are and how to operate them. An experienced driver can "find" the brake pedal with little effort, for example. The practiced driver has learned how to operate the car, scan the road, and check relevant instruments, all more or less simultaneously. With many more cognitive resources available to devote to other tasks, experienced drivers do all sorts of other things while they drive—listen to the radio, talk on car phones, plan their day, rehearse speeches, and so on.

Anyone who has to operate complicated equipment or monitor many instruments simultaneously faces similar challenges. Air traffic controllers, commercial pilots, and medical personnel working in hospital intensive-care wards or emergency rooms must all process a great deal of information from different monitors and instruments—much of it arriving simultaneously—and respond quickly and appropriately. Mistakes in any of these jobs can be costly. The following example, quoted in a study of the design of auditory warning sounds in airplane cockpits (Patterson, 1990), illustrates how too much incoming information can lead to a breakdown in task performance.

> I was flying in a Jetstream at night when my peaceful reverie was shattered by the stall audio warning, the stick shaker, and several warning lights. The effect was exactly what was *not* intended; I was frightened numb for several seconds and drawn off instruments trying to work out how to cancel the audio/visual assault rather than taking what should be instinctive actions. The combined

> assault is so loud and bright that it is impossible to talk to the other crew members, and action is invariably taken to cancel the cacophony before getting on with the actual problem. (p. 485)

Clearly, people who design equipment and instruments should know how people process large amounts of information and how much information we can process at one time. System designers often consult human factors psychologists, who study just these sorts of issues (Wickens, 1987).

My goal in this chapter is to explain what is going on, cognitively speaking, in the preceding examples. More specifically, we will examine the issue of mental resources and how they are assigned to various cognitive tasks. We'll first explore the notion of mental concentration. In particular, I will try to explain what "paying attention" to someone or something means. You will see that at least part of "paying attention" is concentrating—shutting out other activities or information to devote more mental resources to the object on which you want to focus.

We will next take a look at what some recent work in cognitive neuropsychology tells us about brain mechanisms involved when people "pay attention." We will see that particular areas of the brain seem to become active when we pay attention or refocus our attention, and that information that is

L. Lefkowitz/Getty Images

*An operator working with this instrument panel has a great deal of information to monitor simultaneously.*

attended to elicits different responses in the brain from that elicited by unattended information.

We'll also examine how a person's concentration level changes with practice. For many tasks, extensive practice can result in the task's becoming so easy and effortless that performing it requires little attention. When this happens, performance is said to be automatic. This can mean, among other things, that attention is freed up for a person to do another task simultaneously with the automatic one. This topic, known as **divided attention,** has also captured the interest of cognitive psychologists, and will be explored toward the end of this chapter. Finally, we will examine some recent proposals about the relationship between attention and automatic processing.

Like many topics in psychology, attention captured the interest of William James in the late 1800s. James (1890/1983) anticipated the recent writings of investigators studying attention when he argued that only one system or process of conception can go on at a time very easily; to do two or more things at once, he believed, required that the processes be habitual. James's (1890/1983) description of attention, as clear today as it was a hundred years ago, ably sums up the phenomenon psychologists study when they investigate attention:

> Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatterbrained state which in French is called *distraction* and *Zerstreutheit* in German. (pp. 381–382)

## SELECTIVE ATTENTION

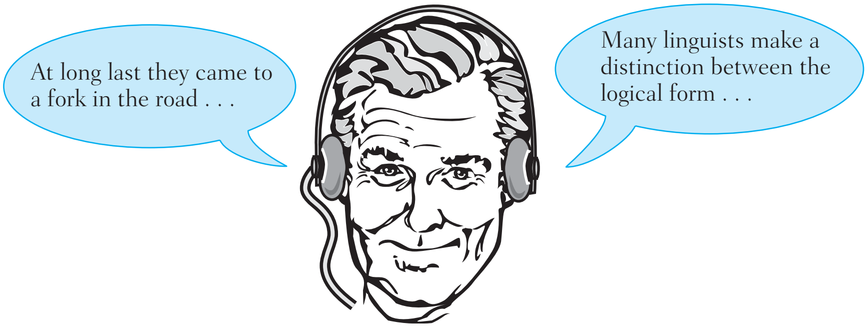
The term **selective attention** refers to the fact that we usually focus our attention on one or a few tasks or events rather than on many. To say we mentally focus our resources implies that we shut out (or at least process less information from) other, competing tasks. As attention researcher Hal Pashler (1998) puts it, "At any given moment, [people's] awareness encompasses only a tiny proportion of the stimuli impinging on their sensory systems" (p. 2).

Do your intuitions agree? Try this experiment. Stop and reflect: Can you hear noises in your environment? Probably, some or all of those noises were there just a second ago, when you read the preceding paragraph. But you weren't paying attention to those noises—they weren't "getting through." Ditto for other stimuli—can you feel your clothes or wristwatch or jewelry against your skin when you direct your attention to them? Probably, although you weren't aware of them a second ago. Presumably we process information differently depending on whether or not we have been actively focusing on a stimulus or not.

How do cognitive psychologists study what information people process about things to which they are not paying attention? If you think about it, this is a tough challenge: How do you present people with information while making sure they do *not* pay attention to it? Simply instructing them to not pay attention is almost guaranteed to have the opposite effect. (Try this: For the next 25 seconds, pay no attention to the feelings in your fingers.)

It turns out that a solution is well known to cognitive psychologists. Depicted in Figure 4-1, it is known as the **dichotic listening task.** It works like this: A person listens to an audiotape over a set of headphones. On the tape are different messages, recorded so as to be heard simultaneously in opposite ears. Participants in a dichotic listening task typically are played two or more different messages (often texts borrowed from literature, newspaper stories, or speeches) and asked to "shadow"—that is, to repeat aloud—one of them. Information is typically presented at a rapid rate (150 words per minute), so the shadowing task is demanding. At the end of the task, participants are asked what information they remember from either message—the attended message or the unattended message. (Sometimes the tapes are recorded so that both messages are heard in both ears—called *binaural presentation*—and some researchers have used it in addition to dichotic listening tasks.)

**FIGURE 4-1** ■ *Depiction of a dichotic listening task. The listener hears two messages and is asked to repeat ("shadow") one of them.*


At long last they came to a fork in the road . . .
Many linguists make a distinction between the logical form . . .

The logic of this experimental setup is as follows: The person must concentrate on the message to be shadowed. Because the rate of presentation of information is so fast, the shadowing task is difficult and requires a great deal of mental resources. Therefore, fewer resources are available to process information from the nonshadowed, nonattended message.

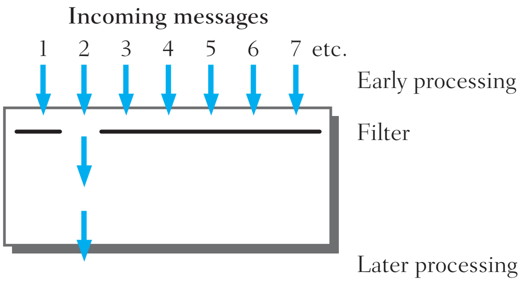
Cherry (1953) demonstrated in a classic study that people can, with few errors, shadow a message spoken at a normal to rapid rate. When researchers later questioned these participants about the material in the unattended message, they could nearly always report accurately whether the message contained speech or noise and, if speech, whether the voice was that of a man or a woman. When the unattended message consisted of speech played backward, some participants reported noticing that some aspect of the message, which they assumed to be normal speech, was vaguely odd.

Participants could not recall the content of the unattended message or the language in which it was spoken. In one variation of the procedure, the language of the unattended message was changed from English to German, but participants apparently did not notice the switch. Participants in another experiment (Moray, 1959) heard prose in the attended message and a short list of simple words in the unattended message. They failed to recognize the occurrence of most words in the unattended message, even though the list had been repeated 35 times!

## Filter Theory

To explain these findings, Broadbent (1958) proposed a **filter theory** of attention, which states that there are limits on how much information a person can attended to at any given time. Therefore, if the amount of information available at any given time exceeds capacity, the person uses an attentional filter to let some information through and block the rest. The filter (see Figure 4-2) is based on some physical (in this particular example, basic acoustic) aspect of the attended message: the location of its source or its typical pitch or loudness, for instance. Only material that gets past the filter can be analyzed later for meaning.

**FIGURE 4-2** ■ *Depiction of a filter model of attention. Different incoming messages, shown as arrows, all arrive at the same time. The filter (black line) blocks all but message 2, which goes on for more cognitive processing.*



This theory explains why so little of the meaning of the unattended message can be recalled: The meaning from an unattended message is simply not processed. Put another way, Broadbent's filter theory maintains that the attentional filter is set to make a selection of what message to process *early* in the processing, typically before the meaning of the message is identified (Pashler, 1998).

Does this mean that people can never pay attention to two messages at once? Broadbent (1958) thought not, believing instead that what is limited is the amount of information we can process at any given time. Two messages that contain little information, or that present information slowly, can be processed simultaneously. For example, a participant may be able to attend simultaneously to more than one message if one repeats the same word over and over again, because it would contain little information. In contrast, messages that present a great deal of information quickly take up more mental capacity; fewer of them can be attended to at once. The filter thus protects us from "information overload" by shutting out messages when we hear too much information to process all at once.

Other investigators soon reported results that contradicted filter theory. Moray (1959) discovered one of the most famous, called the "cocktail party effect": Shadowing performance is disrupted when one's own name is embedded in either the attended or the unattended message. Moreover, the person hears and remembers hearing his name. You may have had a similar experience at a crowded social gathering: While engaged in conversation with one or more people, you hear someone behind you say your name. Until your name was spoken, you "heard" nothing that speaker was saying, but the sound of your name seemed to reach out and grab your attention.

Why does the cocktail party effect pose a problem for filter theory? Filter theory predicts that *all* unattended messages will be filtered out—that is, not processed for recognition or meaning—which is why participants in dichotic listening tasks can recall little information about such messages. The cocktail party effect shows something completely different: People sometimes *do* hear their own name in an unattended message or conversation, and hearing their name will cause them to switch their attention to the previously unattended message.

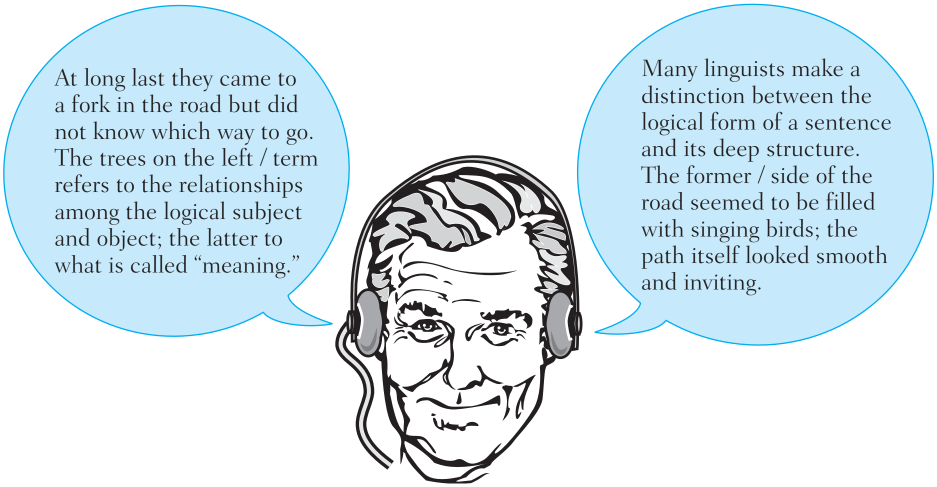
Moray (1959) concluded that only "important" material can penetrate the filter set up to block unattended messages. Presumably, messages such as those containing a person's name are important enough to get through the filter and be analyzed for meaning. Left unexplained, then, is how the filter "knows" which messages are important enough to let pass.

Note that participants did not *always* hear their name in the unattended channel: When not cued in advance to be vigilant, only 33% of the participants ever noticed their names (Pashler, 1998). Thus an alternative explanation for the name recognition finding is that the shadowing task does not always take

100% of one's attention. Therefore, attention occasionally lapses and shifts to the unattended message. During these lapses, name recognition occurs.

Treisman (1960) discovered a phenomenon that argues against this alternative interpretation of the cocktail party effect. She played participants two messages, each presented to a different ear, and asked the participants to shadow one of them. At a certain point in the middle of the messages, the content of the first message and the second message was switched so that the second continued the first and vice versa (see Figure 4-3). Immediately after the two messages "switched ears," many participants repeated one or two words from the "unattended ear." In the example shown, for instance, a participant shadowing message 1 might say, "At long last they came to a fork in the road but did not know which way to go. The trees on the left *side of* refers to the relationships . . . ," with the italicized words following the meaning of the first part of message 1 but coming from the unattended channel (because they come after the switch point). If participants processed the unattended message only when their attentional filter "lapsed," it would be very difficult to explain why these lapses always occurred at the point when the messages switched ears.

**FIGURE 4-3** ■ *Depiction of Treisman's (1960) experimental paradigm. The two messages "switch ears" at the point indicated by the slash mark.*


At long last they came to a fork in the road but did not know which way to go. The trees on the left / term refers to the relationships among the logical subject and object; the latter to what is called "meaning."
Many linguists make a distinction between the logical form of a sentence and its deep structure. The former / side of the road seemed to be filled with singing birds; the path itself looked smooth and inviting.

To explain this result, Treisman reasoned that participants must be basing their selection of which message to attend to at least in part on the meaning of the message—a possibility that filter theory does not allow for. Interestingly, most participants had no idea that the passages had been switched or that they had repeated words from the "wrong ear." Again, this poses a problem for filter theory, which would predict that information from the unattended channel would be shut out.

The issue of whether information from the unattended channel can be recognized was taken up by Wood and Cowan (1995). In one experiment, they had 168 undergraduate participants perform a dichotic listening task. Two of the groups shadowed an excerpt from the *Grapes of Wrath* (read very quickly, at a rate of 175 words per minute) in the attended channel (always presented to the right ear) and were also presented with an excerpt from *2001: A Space Odyssey* in the unattended channel, always presented to the left ear. Five minutes into the task, the speech in the unattended channel switched to backward speech for 30 seconds. Previous experiments had established that under these conditions, roughly half of the participants would notice the switch and half would not. The two groups differed only in how long the "normal" speech was presented after the backward speech: two and a half minutes for one group; one and a half minutes for the other. A third, control group of participants heard an unattended message with no backward speech.

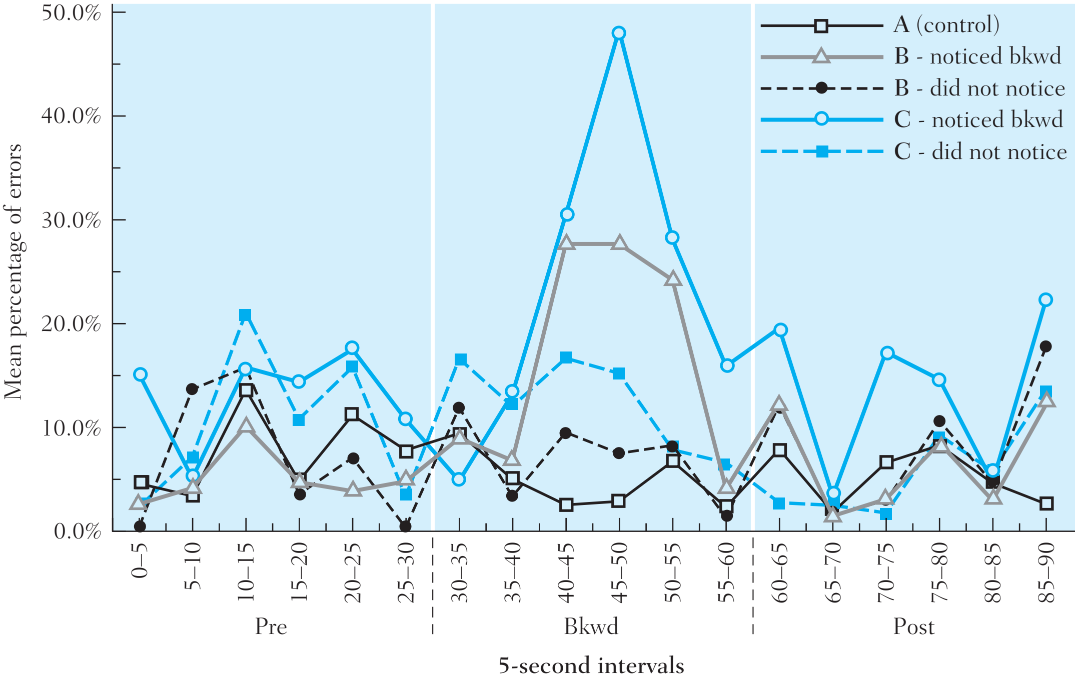
Wood and Cowan (1995) first looked to see whether the people who noticed the backward speech in the unattended message showed a disruption in their shadowing of the attended message. In other words, if they processed information in the unattended message, did this processing have a cost to their performance on the main task? The answer was a clear yes. Wood and Cowan counted the percentage of errors made in shadowing and noted that the percentage rose to a peak during the 30 seconds of the backward-speech presentation. The effect was especially dramatic for those people who reported noticing the backward speech. Control participants, who were never presented with backward speech, showed no rise in their shadowing errors, nor did most of the participants who did not report noticing the backward speech.

What caused the shift in attention to the backward speech? Did the participants (or even some of them) switch their attention back and forth between the two messages periodically? Or did the backward speech cause the attentional filter to be reset automatically (that is, without awareness, intention, or effort)? To address these questions, Wood and Cowan (1995) analyzed shadowing errors by 5-second intervals for the 30 seconds preceding, during, and following the backward-speech segment (for the groups who were presented with backward speech). These findings, presented in Figure 4-4, show that control participants and participants who did not notice the backward speech made no more errors over the time studied. However, participants who did report hearing backward speech made noticeably more errors, which peaked 10 to 20 seconds after the backward speech began.

Wood and Cowan (1995) concluded that the attentional shift to the unattended message was unintentional and completed without awareness. They based this conclusion on the facts that detection of the backward speech interrupted and interfered with shadowing and that error rates peaked in a uniform time for all participants who noticed the backward speech. Put another

**FIGURE 4-4** ■ *Mean percentage of errors in shadowing for each 5-second interval within the 30-second periods immediately before, during, and after backward speech, shown separately for participants who did and did not notice the backward speech. A = control condition; B = backward speech during the first half of the 6th minute; C = same as B but ending after 6 minutes rather than 8.5 minutes. BKWD = backward.*

**SOURCE:** Wood and Cowan (1995, p. 253).



way, Wood and Cowan believed that the participants who noticed the backward speech had their attention "captured" by the backward speech, which led to poorer performance on the main shadowing task.

Indeed, Conway, Cowan, and Bunting (2001) showed that research participants who detect their name in the unattended message are those who have a lower working-memory span. (We'll talk about working memory in the next chapter. For now, you can think of it as the memory "space" or capacity a person has for keeping things in immediate mind.) In fact, 20% of participants with high working-memory spans detected their names in the unattended channel, compared with 65% of participants with low working-memory spans. The authors interpret this finding as follows: A lower working-memory capacity means less ability to actively block the unattended message. In other words, people with low working-memory spans are less able to focus.

## Attenuation Theory

Given her research findings, psychologist Anne Treisman (1960) proposed a modified filter theory, one she called **attenuation theory.** Instead of considering unattended messages completely blocked before they could be processed for meaning (as in filter theory), Treisman argued that their "volume" was "turned down." In other words, some meaningful information in unattended messages might still be available, even if hard to recover. She explained this idea as follows.

Incoming messages are subjected to three kinds of analysis. In the first, the message's physical properties, such as pitch or loudness, are analyzed. The second analysis is linguistic, a process of parsing the message into syllables and words. The third kind of analysis is semantic, processing the meaning of the message.

Some meaningful units (such as words or phrases) tend to be processed quite easily. Words that have subjective importance (such as your name) or that signal danger ("Fire!" "Watch out!") have permanently lowered thresholds; that is, they are recognizable even at low volumes. You might have noticed yourself that it is hard to hear something whispered behind you, although you might recognize your name in whatever is being whispered. Words or phrases with permanently lowered thresholds require little mental effort by the hearer to be recognized. Thus, according to Treisman's theory, the participants in Moray's experiments heard their names because recognizing their names required little mental effort.

Only a few words have permanently lowered thresholds. However, the context of a word in a message can temporarily lower its threshold. If a person hears "The dog chased the . . . ," the word *cat* is **primed**—that is, especially ready to be recognized. Even if the word *cat* were to occur in the unattended channel, little effort would be needed to hear and process it. This explains why people in Treisman's experiment "switched ears": Hearing the previous words in a sentence primed the participants to detect and recognize the words that followed, even when those words occurred in the unattended message.

Similarly, MacKay (1973) showed that the presence of a word in the unattended message (for instance, *river*) helped to "disambiguate" (clarify) the meaning of an ambiguous sentence in the attended message (for instance, "They threw stones toward the bank yesterday"). The sample sentence is ambiguous because the word *bank* could refer to the shores of a river or to a financial institution. If the unattended message consisted of the word *river,* however, the person would understand the sentence to be referring to the shores of a river. To explain this result, we might assume that at least some meaningful aspects of the unattended message are processed. Here, as we saw in Chapter 3, perceiving and attending to information we are expecting is easier than perceiving and attending to unexpected information.

Pashler (1998), however, noted that the effect reported by MacKay (1973) is greatly diminished if the message on the unattended channel consists of a series of words instead of just one. This raises the possibility that if the unattended message consists of one word only, the physical sound of that word temporarily disrupts the attention being paid to the attended message, thus perhaps briefly "resetting" the attentional filter.

According to Treisman (1964), people process only as much as is necessary to separate the attended from the unattended message. If the two messages differ in physical characteristics, then we process both messages only to this level and easily reject the unattended message. If the two messages differ only semantically, we process both through the level of meaning and select which message to attend to based on this analysis. Processing for meaning takes more effort, however, so we do this kind of analysis only when necessary. Messages not attended to are not completely blocked but rather weakened in much the way that turning down the volume weakens an audio signal from a stereo. Parts of the message with permanently lowered thresholds ("significant" stimuli) can still be recovered, even from an unattended message.

Note the contrasts here between attenuation theory and filter theory: Attenuation theory allows for many different kinds of analyses of all messages, whereas filter theory allows for only one. Filter theory holds that unattended messages, once processed for physical characteristics, are discarded and fully blocked; attenuation theory holds that unattended messages are weakened but the information they contain is still available.

## Late-Selection Theory

Broadbent's (1958) filter theory holds that no information about the meaning of an unattended message gets through the filter to be retained for future use. Treisman's (1964) attenuation theory allows for some information about meaning getting through to conscious awareness. Deutsch and Deutsch (1963) proposed a theory, called the **late-selection theory,** that goes even further. Later elaborated and extended by Norman (1968), this theory holds that *all* messages are routinely processed for at least some aspects of meaning—that selection of which message to respond to thus happens "late" in processing.

How much processing occurs? At least the recognition of familiar objects or stimuli. As Pashler (1998) described it, according to late-selection theory,

> Recognition of familiar objects proceeds unselectively and without any capacity limitations. One cannot voluntarily choose to identify or recognize something, according to these theorists. Whether there is just one sensory input or many does not affect the extent to which stimuli are analyzed or the timing of such analyses. (p. 17)

Note that filter theory hypothesizes a *bottleneck*—a point at which the processes a person can bring to bear on information are greatly limited—at the filter. Late-selection theory also describes a bottleneck but locates it later in the processing, after certain aspects of the meaning have been extracted. All material is processed up to this point, and information judged to be most "important" is elaborated more fully. This elaborated material is more likely to be retained; unelaborated material is forgotten.

A message's "importance" depends on many factors, including its context and the personal significance of certain kinds of content (such as your name). Also relevant is the observer's level of alertness: At low levels of alertness (such as when we are asleep), only very important messages (such as the sound of our newborn's cry) capture attention. At higher levels of alertness, less important messages (such as the sound of a television program) can be processed. Generally, the attentional system functions to determine which of the incoming messages is the most important; this message is the one to which the observer will respond.

How well does the evidence for late-selection theory measure up? Different theorists take different positions on this issue. Pashler (1998) argues that the bulk of the evidence suggests it is undeniably true that information in the unattended channel sometimes receives some processing for meaning. At the same time, it appears true that most results thought to demonstrate late selection could be explained in terms of either attentional lapses (to the attended message) or special cases of particularly salient or important stimuli. In any event, it seems unlikely that unattended messages are processed for meaning to the same degree as are attended messages.

## Attention, Capacity, and Mental Effort

Broadbent (1958) originally described attention as a bottleneck that squeezed some information out of the processing area. To understand the analogy, think about the shape of a bottle. The smaller diameter of the bottle's neck relative to the diameter of the bottle's bottom reduces the spillage rate. The wider the neck, the faster the contents can spill. Applying this analogy to cognitive processes, the wider the bottleneck, the more information can "spill through" to be processed further at any point in time.

Modern cognitive psychologists often used different metaphors when talking about attention. For example, some compare attention to a spotlight that highlights whatever information the system is currently focused on (Johnson & Dark, 1986). Accordingly, psychologists are now concerned less with determining what information *can't* be processed (as the bottleneck metaphor highlighted) than with studying what kinds of information people choose to *focus* on (as the spotlight metaphor directs).

To see this, let's consider the spotlight metaphor in a bit more detail. Just as a spotlight's focal point can be moved from one area of a stage to another, so can attention be directed and redirected to various kinds of incoming information. Just as a spotlight illuminates best what is at its center, so too is cognitive processing usually enhanced when attention is directed toward a task.

Attention, like a spotlight, has fuzzy boundaries. Spotlights can highlight more than one object at a time, depending on the size of the objects. Attention, too, can be directed at more than one task at a time, depending on the capacity demands of each task. Of course, the spotlight metaphor is not a perfect one, and some researchers think it has many shortcomings (Cave & Bichot, 1999). For example, the spotlight metaphor assumes that attention is always directed at a specific location, which may not be the case.

Daniel Kahneman (1973) presented a slightly different model for what attention is. He viewed attention as a set of cognitive processes for categorizing and recognizing stimuli. The more complex the stimulus, the harder the processing, and therefore the more resources are engaged. However, people have some control over where they direct their mental resources: They can often choose what to focus on and devote their mental effort to.

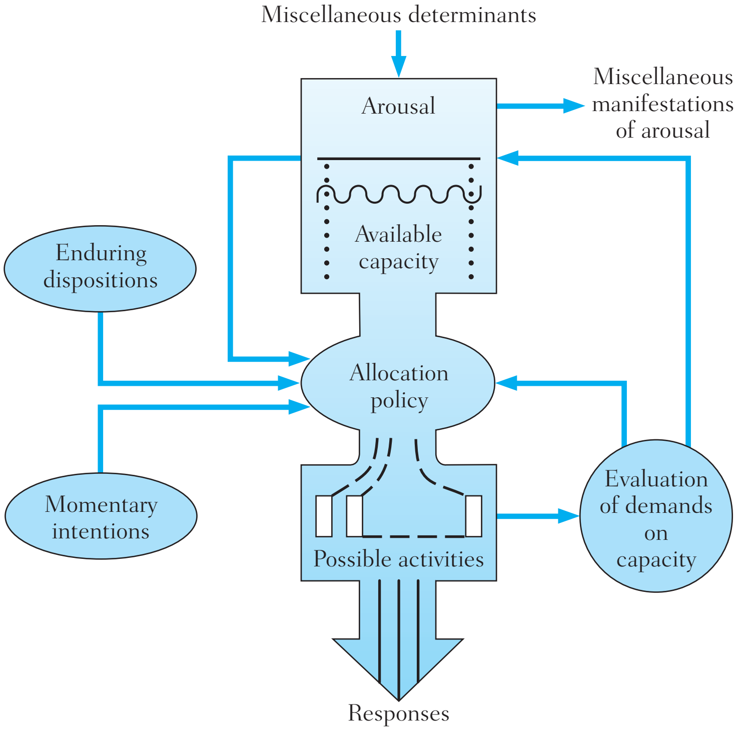
Figure 4-5 presents Kahneman's (1973) model of attention. Essentially, this model depicts the allocation of mental resources to various cognitive tasks. An analogy could be made to an investor depositing money in one or more of several different bank accounts—here, the individual "deposits" mental capacity to one or more of several different tasks. Many factors influence this allocation of capacity, which itself depends on the extent and type of mental resources available. The availability of mental resources, in turn, is affected by the overall level of *arousal,* or state of alertness.

Kahneman (1973) argued that one effect of being aroused is that more cognitive resources are available to devote to various tasks. Paradoxically, however, the level of arousal also depends on a task's difficulty. This means we are less aroused while performing easy tasks, such as adding 2 and 2, than we are when performing more difficult tasks, such as multiplying a Social Security number by pi. We therefore bring fewer cognitive resources to easy tasks, which, fortunately, require fewer resources to complete.

Arousal thus affects our capacity (the sum total of our mental resources) for tasks. But the model still needs to specify how we allocate our resources to all the cognitive tasks that confront us. Look again at Figure 4-5, this time at the region labeled "allocation policy." Note that this policy is affected by an individual's enduring dispositions (for example, your preference for certain kinds of tasks over others), momentary intentions (your vow to find your meal card right now, before doing anything else!), and evaluation of the demands on one's capacity (the knowledge that a task you need to do right now will require a certain amount of your attention).

**FIGURE 4-5** ■ *Kahneman's (1973) model of attention and effort.*

**SOURCE:** Kahneman (1973, p. 10).


Miscellaneous determinants
Arousal
Miscellaneous manifestations of arousal
Available capacity
Enduring dispositions
Allocation policy
Momentary intentions
Possible activities
Evaluation of demands on capacity
Responses

Essentially, this model predicts that we pay more attention to things we are interested in, are in the mood for, or have judged important. For example, opera lovers listen carefully during an operatic performance, concentrating on nuances of the performance. People less interested in opera may sometimes have a hard time even staying awake. In Kahneman's (1973) view, attention is part of what the layperson would call "mental effort." The more effort expended, the more attention we are using.

Kahneman's view raises the question of what limits our ability to do several things at once. We've already discussed arousal. A related factor is alertness as a function of time of day, hours of sleep obtained the night before, and so forth. Sometimes we can attend to more tasks with greater concentration. At other times, such as when we are tired and drowsy, focusing is hard.

Effort is only one factor that influences performance on a task. Greater effort or concentration results in better performance of some tasks—those that require resource-limited processing, performance of which is constrained by the mental resources or capacity allocated to it (Norman & Bobrow, 1975). Taking a midterm is one such task. On some other tasks, one cannot do better no matter how hard one tries. An example is trying to detect a dim light or a soft sound in a bright and noisy room. Even if you concentrate as hard as you can on such a task, your vigilance may still not help you detect the stimulus. Performance on this task is said to be *data limited,* meaning that it depends entirely on the quality of the incoming data, not on mental effort or concentration. Norman and Bobrow pointed out that both kinds of limitations affect our ability to perform any cognitive task.

## Schema Theory

Ulric Neisser (1976) offered a completely different conceptualization of attention, called **schema theory.** He argued that we don't filter, attenuate, or forget unwanted material. Instead, we never acquire it in the first place. Neisser compared attention to apple picking. The material we attend to is like apples we pick off a tree—we grasp it. Unattended material is analogous to the apples we don't pick. To assume the unpicked apples were "filtered out" of our grasp would be ridiculous; a better description is that they simply were left on the tree. Likewise, Neisser believes, with unattended information: It is simply left out of our cognitive processing.

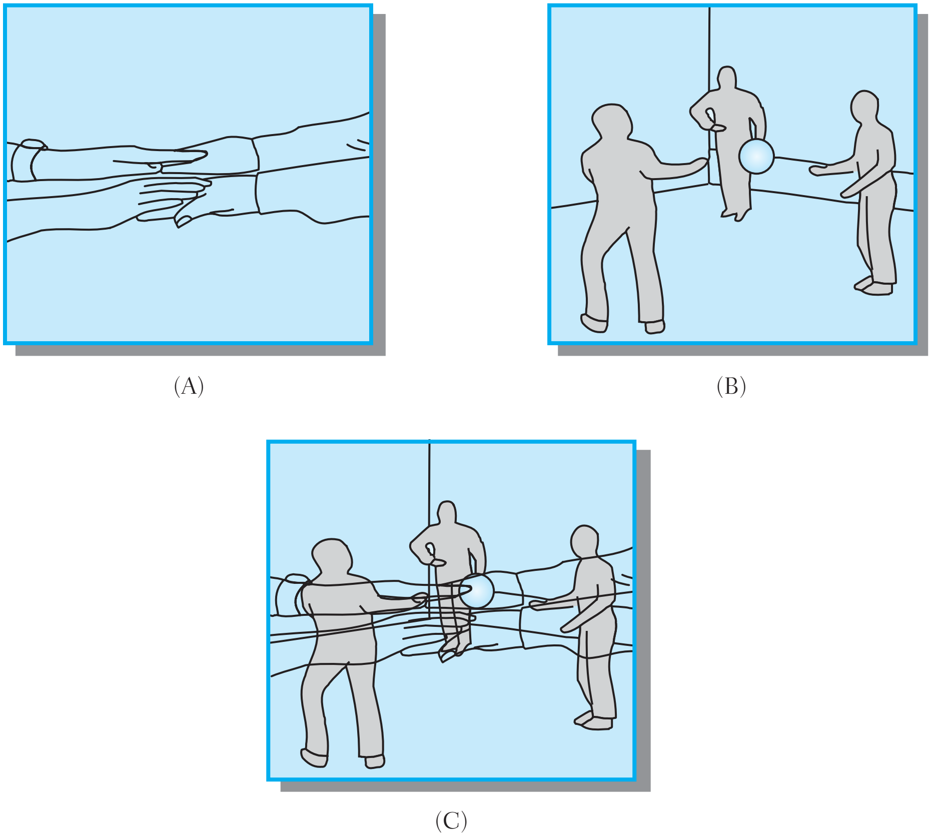
Neisser and Becklen (1975) performed a relevant study of visual attention. They created a "selective looking" task by having participants watch one of two visually superimposed films. Figure 4-6 shows an example of what participants in this study saw. One film showed a "hand game," two pairs of hands playing a familiar hand-slapping game many of us played as children. The second film showed three people passing or bouncing a basketball, or both. Participants in the study were asked to "shadow" (attend to) one of the films and to press a key whenever a target event (such as a hand slap in the first film or a pass in the second film) occurred.

Neisser and Becklen (1975) found, first, that participants could follow the correct film rather easily, even when the target event occurred at a rate of 40 per minute in the attended film. Participants ignored occurrences of the target event in the unattended film.

Participants also failed to notice unexpected events in the unattended film. For example, participants monitoring the ballgame failed to notice that in the hand game film, one of the players stopped hand slapping and began to throw a ball to the other player. Neisser (1976) believed that skilled perceiving rather than filtered attention explains this pattern of performance. Neisser and Becklen (1975, pp. 491–492) argued that once picked up, the continuous and coherent motions of the ballgame (or of the hand game) guide further pickup;

**FIGURE 4-6** ■ *Outline tracings of typical video images used in the Neisser and Becklen (1975) study. (A) shows the hand game alone; (B) the ballgame alone; (C) the hand game and ballgame superimposed.*

**SOURCE:** Neisser and Becklen (1975, p. 485).



(A)

(B)

(C)

what is seen guides further seeing. It is implausible to suppose that special “filters” or “gates,” designed on the spot for this novel situation, block the irrelevant material from penetrating deeply into the “processing system.” The ordinary perceptual skills of following visually given events “are simply applied to the attended episode and not to the other.”

## Inattentional Blindness

Recall in Chapter 3 that we discussed the phenomenon of *change blindness,* the inability to notice large changes to scenes when the scene is somehow disrupted (Simons, Nevarez, & Boot, 2005). Change blindness has been linked to another phenomenon known as **inattentional blindness,** the phenomenon of not perceiving a stimulus that might be literally right in front of you, unless you are paying attention to it (Mack, 2003; Simons & Ambinder, 2005). Mack gives the following everyday example of inattentional blindness:

> Imagine an experienced pilot attempting to land an airplane on a busy runway. He pays close attention to his display console, carefully watching the airspeed indicator on his windshield to make sure he does not stall, yet he never sees that another airplane is blocking his runway! (p. 180)

You may be skeptical that such a phenomenon really does happen. After all, how can a (nonpsychotic) person be looking at an object and not really see it? One answer can be found in the Neisser and Becklen experiment described previously—research participants failing to "see" an unexpected event. A more dramatic (and humorous) demonstration again comes from the laboratory of Daniel Simons, who partially replicated the Neisser and Becklen (1975) studies using more sophisticated video technology.

Figure 4-7 depicts four experimental conditions (each research participant was assigned to only one condition). As in the Neisser and Becklen (1975) studies, participants were asked to follow either the "white team" or the "black team" and to count the number of times the team they were watching passed a basketball (Easy condition) or to keep track separately of both the number of bounce passes and the number of aerial passes made by the target team (Hard condition). At a little under a minute into the presentation, an unexpected event occurred:

> After 44–48 s of this action, either of two unexpected events occurred: in the Umbrella-Woman condition, a tall woman holding an open umbrella walked from off camera on one side of the action to the other, left to right. The actions of the players, and this unexpected event, were designed to mimic the stimuli used by Neisser and colleagues. In the Gorilla condition, a shorter woman wearing a gorilla costume that fully covered her body walked through the action in the same way. In either case, the unexpected event lasted 5 s, and the players continued their actions during and after the event. (Simons & Chabris, 1999, p. 1066)

After viewing the entire videotape, students first wrote down their counts and then were asked to describe anything unusual they had seen on the video. Questions became increasingly specific, beginning with "While you were doing the counting, did you notice anything unusual on the video?" and ending with "Did you see a gorilla (or a woman carrying an umbrella) walk across the screen?"

Images not available due to copyright restrictions

Overall, 46% of participants failed to notice either the umbrella woman or the gorilla. Only 44% of participants ever reported seeing a gorilla, although this number was much greater for the subjects watching the black team, who presumably shared more visual features with the gorilla (dark color) than did the white team (see Table 4-1 for a full presentation of results). Simons and Chabris (1999) concluded that unexpected events can be overlooked. Presumably, we only perceive those events to which we attend, especially if the unexpected event is dissimilar to the focus of our attention, and if our attention is tightly focused somewhere else.

**Table 4-1** **Percentage of subjects noticing the unexpected event in each condition. Each row corresponds to one of the four video display types. Columns are grouped by monitoring task and attended team (White or Black). In the Easy task, subjects counted the total number of passes made by the attended team. In the Hard task, subjects maintained separate simultaneous counts of the aerial and bounce passes made by the attended team.**

| | *Easy task* | | *Hard task* | |
|---|---|---|---|---|
| | *White team* | *Black team* | *White team* | *Black team* |
| ***Transparent*** | | | | |
| Umbrella Woman | 58 | 92 | 33 | 42 |
| Gorilla | 8 | 67 | 8 | 25 |
| ***Opaque*** | | | | |
| Umbrella Woman | 100 | 58 | 83 | 58 |
| Gorilla | 42 | 83 | 50 | 58 |

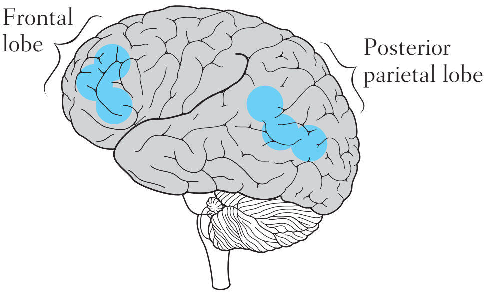
**Source:** Simons and Chabris (1999, p. 1068).

## NEUROSCIENTIFIC STUDIES OF ATTENTION

Cognitive neuroscientists are interested in examining which areas of the human brain are active when a person is attending to a stimulus or event. Researchers have long suspected the parietal lobe of the brain (see Figure 4-8) is one such location.

**FIGURE 4-8** ■ *Areas of the brain active during attentional processing. A view of the left cerebral hemisphere.*

**SOURCE:** Banich (1997, p. 243).



Clinical neurologists have documented the phenomenon of sensory neglect (sometimes called hemineglect) in patients who have parietal lobe damage. (You may recall some discussion of hemineglect in Chapter 3.) These patients often ignore or neglect sensory information located in the visual field opposite to the damaged hemisphere. Thus if an area of the right parietal lobe is the damage site (as it often is), the patient overlooks information in the left visual field. This neglect may include, for example, neglecting to wash one side of the face or body, neglecting to brush the teeth on one side of the mouth, or eating from only one side of the plate.

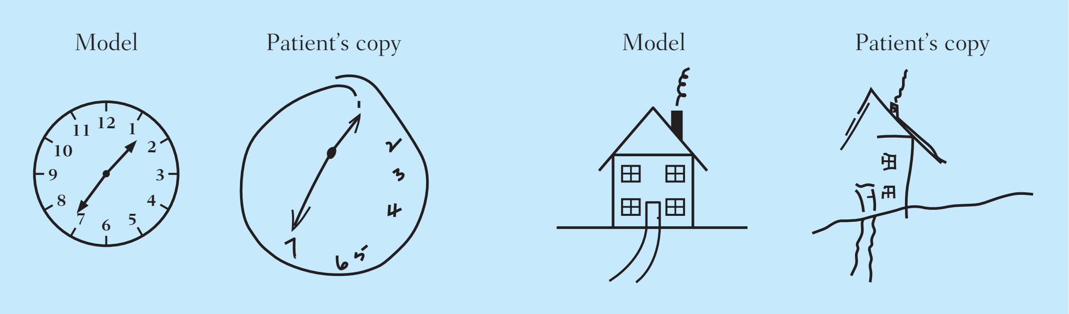
In clinical studies, patients showing hemineglect have been studied in more detail. Typically, they are presented with stimuli and asked to copy them. Figure 4-9 shows examples of stimuli presented to a patient with right parietal lobe damage and the patient's drawings. Note that in both cases the left part of the drawing is missing, something the patient did not appear to notice.

Clinical work has established that hemineglect is attentional, rather than sensory (Banich, 1997). Were it simply a sensory deficit, we would expect patients to turn their gaze to the part of the visual field they were missing—in other words, to be aware their visual information is incomplete. Indeed, some patients have just this type of deficit, and they do compensate by just such strategies. In contrast, patients with hemineglect seem unaware of one side of their body and disinclined to try to attend to information from that side. In extreme cases, patients with hemineglect even deny that some of their own limbs belong to them. In one case study, a patient thought hospital staff had cruelly placed a severed leg in his bed; he tried to throw it to the floor, but the rest of his body followed the leg (Banich, 1997).

Although the parietal lobe is one brain region known to be associated with attention, it is not the only one. Areas of the frontal lobe as well (see Figure 4-8) play a role in people's ability to select motor responses and develop

**FIGURE 4-9** ■ *When a patient with a lesion of the right parietal lobe is asked to copy simple line drawings such as a clock or a house, he omits details on the left.*

**SOURCE:** Posner and Raichle (1994, p. 158).



plans (Milham, Banich, Webb, Barad, Cohen, Wszalek, & Kramer, 2001). But how do the various brain regions communicate with each other to produce attentional performance? This question is clearly significant, and I will provide only a short, focused answer, by looking specifically at one kind of attention.

## Networks of Visual Attention

Much work on brain processes of attention has centered on visual attention. Researchers have identified more than 32 areas of the brain that become active during visual processing of an attended stimulus (LaBerge, 1995). We obviously don't have the time or room to perform a detailed review of each. Instead, we will focus on three "networks" or systems of visual attention proposed by Posner and Raichle (1994).

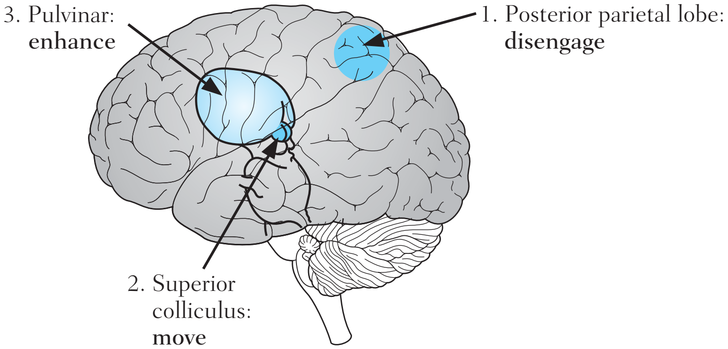
In a series of studies, Posner and his colleagues used the following task. A participant is seated in front of a visual display, fixating on a central point. On either side of the point are two boxes. On each trial, one box brightens or an arrow appears, indicating on which side of the screen the participant should expect to see the next stimulus. The purpose of this cue is to encourage the participant to focus his or her attention at a particular location. The participant's task is to respond as fast as possible when he detects the stimulus. Sometimes no cue is given, and at other times an incorrect cue is given, to assess the benefit of having attention focused in either the correct or an incorrect location (Posner & Raichle, 1994).

Posner and Raichle (1994) argued that to perform this task, a person needs to execute three distinct mental operations. She first must *disengage* her attention from wherever it was previously directed. Brain activity in the posterior parietal lobe (see Figure 4-10) is heightened during this process. Once disengaged, attention must be refocused on the spatial location of the new to-be-attended stimulus. Posner and Raichle called this the *move* operation. They reported that patients with brain damage in the superior colliculus, a major structure of the midbrain (see Figure 4-10), have difficulty moving their attention from one location to another. Finally, according to Posner and Raichle, when attention is redirected, neural processing of the new location is *enhanced*; stimulus information presented at the to-be-attended location is emphasized, and the brain circuitry underlying this operation (the pulvinar, located in the thalamus; see Figure 4-10) becomes more active. As you might expect, patients with damage to the pulvinar do not show the enhanced processing of which other people are capable when attending to a stimulus in a particular location.

The idea that attention consists of several different processes that operate independently has received some support from clinical psychological studies of children and adults with ADHD, attention-deficit/hyperactivity disorder

**FIGURE 4-10** ■ *The three areas of the orienting network perform three functions required to orient attention. The focus of attention is first disengaged from a cue, then moved to the expected target location; finally, the target at the location being attended is enhanced.*

**SOURCE:** Posner and Raichle (1994, p. 168).



(Barkley, 1998; Rubia & Smith, 2001; Woods & Ploof, 1997). An estimated 3% to 5% of the general school-age population has some form of ADHD (Casat, Pearson, & Casat, 2001), with the disorder approximately three times more common in boys than girls. Barkley's (1998) classic work suggests that ADHD clients suffer not so much from an inability to be alert or to devote mental resources to a task (Posner and Raichle's disengage and move operations) as from an inability to sustain vigilance on dull, boring, repetitive tasks, such as "independent schoolwork, homework, or chore performance" (Barkley, 1998, p. 57). Logan, Schachar, and Tannock (2000) suggest that in fact the major deficit in ADHD children is an inability to inhibit an ongoing response (for example, talking or playing a game when asked to do homework), an inability that may be a part of Posner and Raichle's enhance operation.

Posner and Raichle's (1994) description of attentional networks postulated that distinct areas of the brain underlie distinct cognitive processes. Posner more recently has described three different attentional networks that recruit individual cognitive processes (such as moving or disengaging). These are the alerting network, responsible for achieving and maintaining an alert state; the orienting network, which selects information from sensory input; and the executive control network, which resolves conflicts among different responses (Fan, McCandliss, Sommer, Raz, & Posner, 2002; Posner & Fan, 2001). Posner believes that the alerting network is associated with the frontal and parietal regions of the right hemisphere; the orienting network with areas of both the parietal and frontal areas; and the executive control network with the frontal lobes, especially the prefrontal cortex.

## Event-Related Potentials and Selective Attention

Cognitive neuropsychologists have reported some fairly dramatic findings suggesting that information is processed very differently in attended versus unattended channels. Some of this work relies on measures such as a series of electrical potential recordings (electroencephalogram, or EEG) taken from the scalp of a participant. For technical reasons, researchers often average EEG records over many trials to reduce noise, ending up with the average electrical potential recorded 1 millisecond after presentation of a stimulus, 2 milliseconds after a stimulus, and so forth. This procedure results in a measure, already introduced briefly in Chapter 2, called an **event-related potential (ERP).**

Banich (1997) has described the methodology of a typical study. Participants are asked to listen to one channel and to count long-duration tones. Short-duration tones and long-duration tones are both presented in each channel, attended and unattended. Researchers keep track of the ERPs to each stimulus. Results from many studies show that ERPs differ as a function of whether a stimulus was attended to (Pashler, 1998). Figure 4-11 presents an example of some

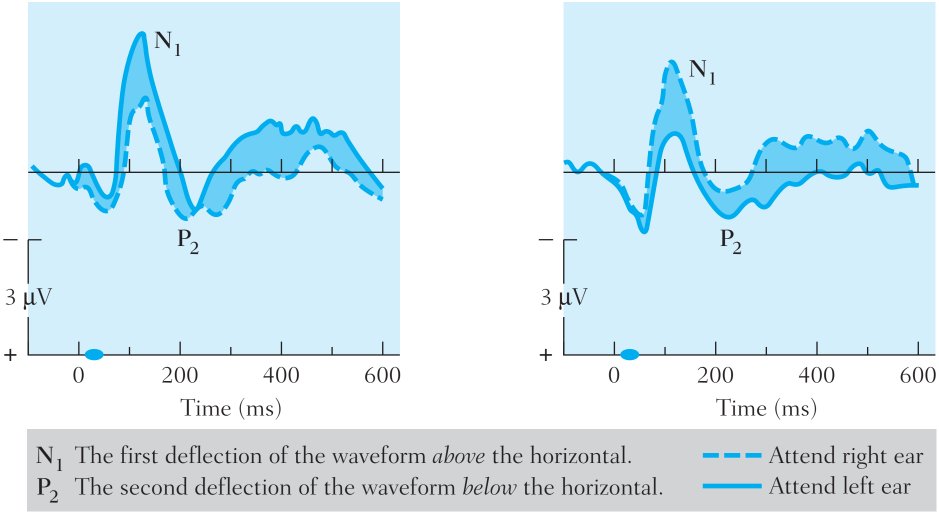


**FIGURE 4-11** ■ *Modulation of early event-related potential (ERP) components by attention. The response to the stimulus is enhanced when it is presented in the attended location as compared with when it is not. (Left) For example, the amplitude of the $N_1$ is greater to a left-ear tone when the individual is attending to the left ear (solid line) than when the same tone is heard but the individual is attending to the right ear (dotted line). (Right) Likewise, the response to a right-ear tone is greater when the right ear is attended (dotted line) than when the left is (solid line). The difference between these two waveforms (shaded area) is the $N_d$ component. This effect begins relatively soon after stimulus presentation, within the first 100 milliseconds.*

**SOURCE:** Banich (1997, p. 239).

typical results. Notice that the amplitude of the waveforms (that is, how much the waveform deviates from the horizontal) is usually much larger for the attended than for the unattended stimulus. This difference usually begins 80 milliseconds after presentation of the stimulus, which is enough time for information to travel from the sensory receptors in the ears to the cerebral hemispheres, suggesting that the effect occurs in the brain, not in the ears (Banich, 1997).

## AUTOMATICITY AND THE EFFECTS OF PRACTICE

As we become well practiced doing something, that act takes less of our attention to perform. Typing is a good example. If you are skilled at typing, you can probably type fairly quickly and accurately and can do so while you carry on a conversation or even look out the window. If you aren't very skilled, then you type more slowly, make more errors, and are less able to process other incoming information. More formally said, an important variable that governs the number of things we can do simultaneously is the capacity a given task consumes. Adding 2 and 3 consumes little of my capacity, leaving some for other tasks (such as planning dinner tonight and wondering if I have all the ingredients at home).

What affects the capacity any given task requires? One factor is obviously the difficulty of the task. Another is the individual's familiarity with the task. Although easy for me, adding 2 and 3 still challenges a 5-year-old. The difference between us on this task is practice—I've added 2 and 3 far more often than any 5-year-old has. Practice is thought to decrease the amount of mental effort a task requires.

Recall the earlier example of a novice automobile driver. The unpracticed task of controlling a car in motion requires so much mental effort that little capacity is available for other tasks, such as tuning a radio or responding to a conversation. Even coordinating driving with looking at the relevant instruments on the dashboard may be difficult, because the novice driver's mental energy is so intently focused. With just a few months' practice, however, a driver needs much less effort for the driving task itself. Mental capacity is now available for other tasks, and the driver can steer and talk at the same time. However, a complicated situation (such as a traffic accident during rush hour) requires even the most practiced driver to pay more attention, temporarily reducing his or her ability to converse or sing along with the radio.

### The Stroop Task

A famous demonstration of the effects of practice on the performance of cognitive tasks was given by John Ridley Stroop (1935). Stroop presented participants with a series of color bars (red, blue, green, brown, purple) or color words (*red, blue, green, brown, purple*) printed in conflicting colors (the word *red,* for example, might be printed in green ink). On the inside cover of this book, you can see an example of stimuli similar to those Stroop used.

Participants were asked to name, as quickly as possible, the ink color of each item in the series. When shown bars, they did so quickly, with few errors and apparently little effort. Things changed dramatically, however, when the items consisted of words that named colors other than that of the ink in which the item was printed. Participants stumbled through these lists, finding it difficult not to read the word formed by the letters.

According to Stroop (1935), the difficulty stems from the following: Adult, literate participants have had so much practice reading that the task requires little attention and is performed rapidly. In fact, according to Stroop, literate adults read so quickly and effortlessly that *not* reading words is hard. Thus when confronted with items consisting of words, participants couldn't help reading them. We describe this kind of response—one that takes little attention and effort and is hard to inhibit—as *automatic*.

The actual task given to participants, to name colors, was one they had practiced much less. Participants in one of Stroop's (1935) subsequent experiments, given eight days of practice at the naming task, in fact showed less interference in performing the so-called **Stroop task** and became faster at naming colors with all stimuli. Moreover, a summary of the literature suggests that Stroop interference begins when children learn to read, peaking at around second or third grade (when reading skills develop) and then declining over the adult years until about age 60 (MacLeod, 1991). Virtually everyone who can read fluently shows a robust Stroop effect from an early age.

## Automatic Versus Attentional (Controlled) Processing

What exactly does it mean to perform a task "automatically"? We often talk about being "on autopilot" when we do something without being aware of it—but what is actually going on cognitively? Posner and Snyder (1975) offered three criteria for cognitive processing to be called **automatic processing:** (1) It must occur without intention; (2) it must occur without involving conscious awareness; and (3) it must not interfere with other mental activity.

Let's consider our driving example once again. A practiced driver driving a familiar route under normal, nonstressful conditions may well be operating the car automatically. Driving home, for example, I've often found myself in the middle of making a turn without actually intending to: My hand seems to hit the turn signal and my arms to turn the steering wheel without my consciously deciding to do so. Indeed, sometimes I follow my usual route home even when I've previously intended to go a different way. For example, I may intend to go

Red
Yellow
Blue
Orange
White
green

Nancy J. Ashmore

*As children acquire reading skills, they also start to show interference on the Stroop task.*

to the dry cleaners but start thinking of something else and then, to my surprise and embarrassment, will find myself in my own driveway, simply because I forgot to change my automatic routine!

Schneider and Shiffrin (1977) examined automatic processing of information under well-controlled laboratory conditions. They asked participants to search for certain targets, either letters or numbers, in different arrays of letters or numbers, called *frames*. For example, a participant might be asked to search for the target *J* in an array of four letters: *B M K T*. (*Note*: This trial is "negative," in the sense that the target is not present in the frame.)

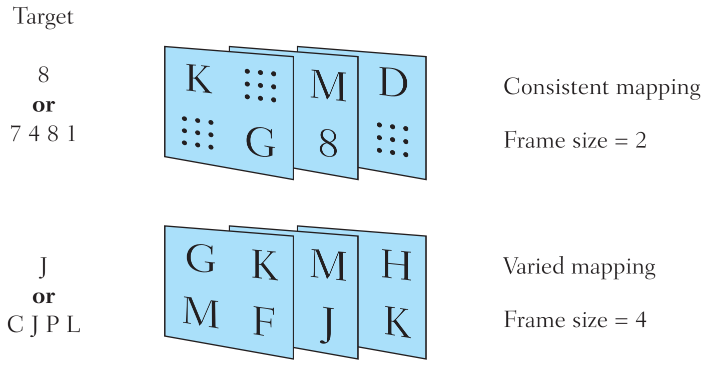
Previous work had suggested that when people search for targets of one type (such as numbers) in an array of a different type (such as letters), the task is easy. Numbers against a background of letters seem to "pop out" automatically. In fact, the number of nontarget characters in an array, called distractors, makes little difference *if* the distractors are of a different type from the targets. So finding a *J* among the stimuli *1, 6, 3, J, 2* should be about as easy as finding a *J* among the stimuli *1, J, 3*. Finding a specific letter against a background of other letters seems much harder. So searching for *J* among the stimuli *R J T* is easier than searching for the *J* among the stimuli *G K J L T*. In other words, when the target and the distractors are of the same type, the number of distractors does make a difference.

Schneider and Shiffrin (1977) had two conditions in their experiment. In the varied-mapping condition, the set of target letters or numbers, called the *memory set,* consisted of one or more letters or numbers, and the stimuli in each frame were also letters or numbers. Targets in one trial could become distractors in subsequent trials. So a participant might search for a *J* on one trial, then search for an *M* on the second trial, with a *J* distractor included. In this condition, the task was expected to be hard and to require concentration and effort.

In the consistent-mapping condition, the target memory set consisted of numbers and the frame consisted of letters, or vice versa. Stimuli that were targets in one trial were never distractors in other trials. The task in this condition was expected to require less capacity. Figure 4-12 provides examples of some of the stimuli Schneider and Shiffrin might have used.

**FIGURE 4-12** ■ *Depiction of stimuli presented to research participants in the Schneider and Shiffrin (1977) study.*

**SOURCE:** Adapted from Schneider and Shiffrin (1977). Reprinted by permission of Lise Abrams.

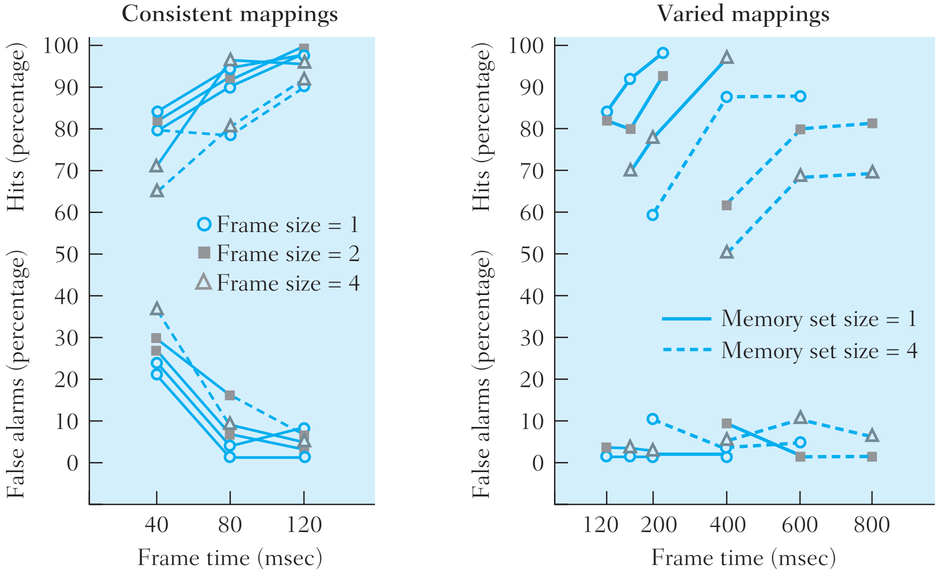


In addition, Schneider and Shiffrin (1977) varied three other factors to manipulate the attentional demands of the task. The first was *frame size*—that is, the number of letters and numbers presented in each display. This number was always between 1 and 4. Slots not occupied by a letter or number contained a random dot pattern. Second was the *frame time*—that is, the length of time each array was displayed. This varied from approximately 20 milliseconds to 800 milliseconds. The last variable manipulated was the *memory set*—that is, the number of targets the participant was asked to look for in each trial (for example, find a *J* versus find a *J, M, T,* or *R*).

Figure 4-13 presents the results of the Schneider and Shiffrin (1977) study. The graphs are a little hard to follow, but try to do so in conjunction with what you read in the next few paragraphs. In the consistent-mapping condition, thought to require only automatic processing (because the targets and distractors were not the same type of stimuli), participants' performance varied only with the frame time, not with the number of targets searched for (memory set) or the number of distractors present (frame size). This means participants were just as accurate in searching for one as for four targets and in searching among one, two, or four items in a frame. Accuracy depended *only* on the length of time the frames were displayed.

**FIGURE 4-13** ■ *Results of Schneider and Shiffrin's (1977) experiments. Notice that for subjects in the consistent-mapping condition, only the variable of frame time affects reaction time. Subjects in the varied-mapping condition are also affected by frame size and memory set size.*

**SOURCE:** Schneider and Shiffrin (1977, p. 12).



In the varied-mapping condition, thought to require more than automatic processing (because the targets and distractors could both be letters, or both numbers, and because targets on one trial could become distractors on another), participants' performance in detecting the target depended on all three variables: memory set size (number of targets searched for), frame size (number of distractors present), and frame time. You can see this in the second panel of Figure 4-13, where all the lines are separated, indicating that participants responded differently on trials with different memory set sizes and/or different frame sizes.

Schneider and Shiffrin (1977) explained these results by distinguishing between two kinds of processing. Automatic processing, they asserted, is used for easy tasks and with familiar items. It operates in parallel (meaning it can operate simultaneously with other processes) and does not strain capacity limitations. This kind of processing is done in the consistent-mapping condition: Because the targets "popped out" from the background, little effort or concentration was required. That searching for four targets was as easy as searching for one illustrates the parallel nature of this kind of processing: Several searches can be conducted simultaneously.

Schneider and Shiffrin (1977) dubbed the second kind **controlled processing.** Controlled processing is used for difficult tasks and ones that involve unfamiliar processes. It usually operates serially (with one set of information processed at a time), requires attention, is capacity limited, and is under conscious control. Controlled processing occurred in the varied-mapping condition (where targets and distractors could alternate across different trials). More generally, controlled processing is what we use with nonroutine or unfamiliar tasks.

Can we learn to use automatic processing in place of controlled processing for a task? Much work suggests we can, with massive amounts of practice in a task. Bryan and Harter (1899) first made this point in an early study of the development of the ability to receive and send telegraph messages. They found, first, that with practice people got better at both sending and receiving telegraphed messages. Second, their participants reported that as they became accustomed to the task, they shifted the focus of their attention. At first they struggled simply to send or receive individual letters. After a few months, they concentrated on words rather than on individual letters. Still later, their focus shifted again, this time from words to phrases or groups of words. Practice apparently made individual responses (such as detection of a letter) automatic, or "habits," as Bryan and Harter called them, freeing attention for higher-level responses (words instead of letters, phrases instead of words).

If you play video games, you may have noticed a similar kind of learning effect. When you first play a new game, learning how to operate the controls to move your video figure across the screen probably takes a while. (My first game of Mario Brothers, for instance, lasted approximately 15 seconds.) At first, you need full concentration to figure out when, where, and how to move your figure about the screen. You have little capacity left to notice impending danger.

With practice, playing the game takes much less effort. I know "expert" Mario Brothers players (sadly for my ego, they are a fraction of my age and educational level) who can play 30-minute games and still have enough cognitive resources left to carry on an extended discussion with me! My information processing in playing Mario Brothers is still of the controlled sort. My young friends, because of their extensive practice, now process much of the information automatically.

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*Even a young, experienced video game player can begin to play with very little cognitive effort.*

## Feature Integration Theory

By now you may be wondering about the role attention and automaticity play in perception, and vice versa, because many experiments we've talked about in this chapter certainly involve the perception and recognition of familiar stimuli. Anne Treisman, inspired by the work of Schneider and Shiffrin, investigated this question, developing what has come to be called **feature integration theory.** Her general idea is that we perceive objects in two distinct stages. In the first stage, which is preattentive, or automatic, we register features of objects, such as their color or shape. In the second stage, attention allows us to "glue" the features together into a unified object (Tsal, 1989a).

Treisman reported several experimental results that support feature integration theory. In one experiment (Treisman & Gelade, 1980), researchers presented participants with a series of simple objects (such as letters) that differed in several features (such as color or shape). Participants were asked to search for a particular object—for example, a pink letter or the letter *T*. If the item being searched for differed from the background items in the critical feature (such as a pink item among green and brown items, or a *T* among *O*'s), the target item seemed to pop out of the display, and the number of background items did not affect participants' reaction times. Treisman and Gelade interpreted this pattern of results as evidence that the detection of individual features is automatic—that is, requiring little attention or concentration and occurring in parallel. As a result, detecting a circle or the color blue or any other single feature is relatively easy. You can check out this phenomenon for yourself with the stimuli shown on the inside cover of the book.

In another condition, participants were asked to search for an object with a combination of features—such as a pink *T*—against a background of objects that had one or the other feature (in this example, both pink items that were not *T*'s, and *T*'s that were not pink). In this condition, participants' reaction times varied with the number of background items. Treisman and Gelade (1980) argued that searching for a conjunction, or combination, of features requires controlled, nonautomatic processing.

Interestingly, in a later study Treisman and Schmidt (1982) showed that when attention is diverted or "overloaded," participants make integration errors, resulting in what Treisman called *illusory conjunctions*. Consider the example of glancing quickly and without much attention out the window at a red Honda Civic and a blue Cadillac. Later, when asked to report what you saw, you might say, "A blue Honda Civic." Such combining of two stimuli is erroneous; the conjunction reported is illusory.

In the experimental demonstration of this phenomenon (Treisman & Schmidt, 1982), participants saw two black digits displayed on either side of a row of three larger colored letters, presented briefly (for 200 milliseconds).

They were asked to pay attention to and recite the black digits, with the experimenter emphasizing the importance of accuracy. Participants were also asked, *after* they had reported the digits, to report the positions (left, right, or middle), colors, and names of any letters they had seen. They were asked to report only information about which they were highly confident. Participants were able to provide correct information on letters 52% of the time, but in 39% of the trials they reported illusory conjunctions (such as a red *X* instead of either a blue *X* or a red *T*). In other words, when mentally taxed, people mistakenly combined features in illusory conjunctions.

Putting these ideas together, Treisman argued that individual features can be recognized automatically, with little mental effort. What apparently requires mental capacity is the integration of features, the putting together of pieces of information to recognize more complicated objects. Thus, according to Treisman, perceiving individual features takes little effort or attention, whereas "gluing" features together into coherent objects requires more. Many researchers (Briand & Klein, 1989; Quinlan, 2003; Tsal, 1989a, 1989b) have tested the theory's predictions and offered refinements and critiques.

## Attentional Capture

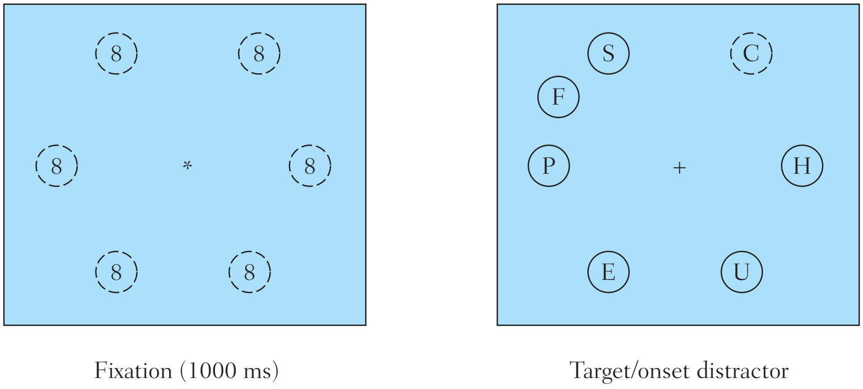
The work just reviewed on visual search tasks often involves "pop out" phenomena in which certain stimuli seem to jump off the page or screen at the viewer, demanding attention. Experimental psychologists have called this phenomenon **attentional capture.** By this, they mean to imply that certain stimuli "cause an involuntary shift of attention" (Pashler, Johnston, & Ruthruff, 2001, p. 634). Many have described this phenomenon as a bottom-up process, driven almost entirely by properties of a stimulus, rather than by the perceiver's goals or objectives. Hence, the term *attentional capture,* which implies that the stimulus somehow automatically attracts the perceiver's attention (Yantis, 2000; Yantis & Egeth, 1999).

For example, in studies by Theeuwes, Kramer, Hahn, and Irwin (1998) participants viewed displays such as the one shown in Figure 4-14. At first, as depicted by the left-hand side of the figure, participants saw six gray circles (depicted in the figure by dashed lines) with small figure 8's inside. After 1000 milliseconds, all but one of the gray circles changed to red (depicted in the figure by solid lines), and all the figure 8's changed to letters. Only one of the circles remained gray. Participants were instructed to move their eyes to the only gray circle and to decide as quickly as possible if the letter it contained was a *C* or a reverse *C*.

On half the trials, at the time when the gray circles changed to red, another (seventh) red circle suddenly appeared, without forewarning, somewhere on the screen. Even though this new object was irrelevant to the task, it tended to

**FIGURE 4-14** ■ *Stimuli from the Theeuwes et al. study of attentional capture.*

**SOURCE:** Theeuwes, Kramer, Hahn, and Irwin (1998, Figure 1, p. 380).



draw the participants' eyes toward it, delaying their reaction time to make a decision. However, when participants in a follow-up study (Theeuwes, Atchley, & Kramer, 2000) were first warned to attend to a specific location (where the single remaining gray circle would be), they did not have their attention "captured" by the appearance of a new, irrelevant stimulus. This suggests that, with enough time, top-down processes intentionally controlled by a participant can override the passive and reflexive attentional capture.

## ■ DIVIDED ATTENTION

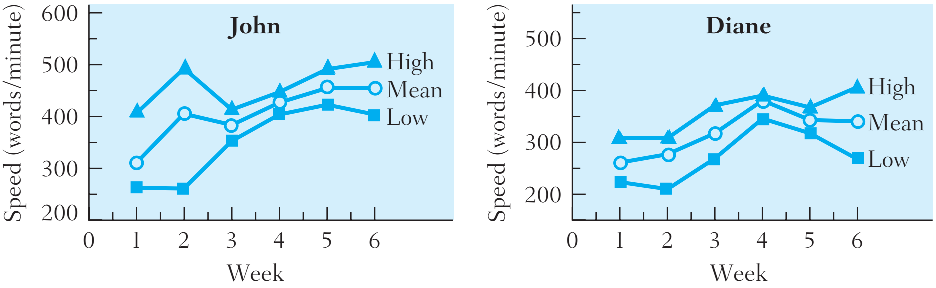
If attention is a flexible system for allocating resources, and if tasks differ in the amount of attention they require, then people should be able to learn to perform two tasks at once. Parents of teenagers, for example, often marvel over how their children seem able to listen to music, talk on the phone to their friends, and study all at the same time. How difficult is doing two or more tasks at once, and on what factors does this ability depend?

### Dual-Task Performance

Spelke, Hirst, and Neisser (1976) examined this question in a clever and demanding laboratory study. Two Cornell University students were recruited as participants. Five days a week, for 17 weeks, working in 1-hour sessions, these students learned to write words dictated while they read short stories. Their reading comprehension was periodically tested. After 6 weeks of practice, their reading rates (shown in Figure 4-15) approached their normal speeds. Also by

**FIGURE 4-15** ■ *Reading speeds during practice phase of learning to do two things at once. Weekly means and interquartile ranges of reading speeds, plotted for each week of practice, for two subjects, John and Diane.*

**SOURCE:** Adapted from Spelke et al. (1976, p. 220).



the end of 6 weeks, their scores on the reading comprehension tests were comparable whether they were only reading stories (and thus presumably giving the reading task their full attention) or reading stories while writing down dictated words. Further investigation revealed that participants could also categorize the dictated words by meaning and could discover relations among the words without sacrificing reading speed or comprehension.

Many psychologists were surprised that the participants in this study could process information about meaning without conscious attention, and some offered alternative explanations for the findings. One hypothesis is that participants alternated their attention between the two tasks, attending first to the story, then to the dictation, then back to the story, and so on. Although this possibility was not directly tested, the authors argued the fact that the participants' reading speeds were comparable whether or not they were taking dictation suggests that if they were alternating their attention, they were doing so without any measurable lag.

Hirst, Spelke, Reaves, Caharack, and Neisser (1980) found evidence against this alternation hypothesis. Their participants were trained in ways similar to those used by Spelke et al. (1976). All participants copied dictated words while reading. Some participants read short stories, presumably containing some redundant material and therefore requiring relatively little attention. Other participants read encyclopedia articles, thought to contain less redundant material and thus to require more concentration. After they reached normal reading speeds and reading comprehension during dictation, the participants' tasks were switched: Those who had been reading short stories were now given encyclopedia articles, and those trained using encyclopedia articles now read short stories. Six of the seven participants performed comparably with the new reading material, indicating that the participants were probably not alternating their attention between the two tasks. If they were, then learning to take dictation while reading short stories should not transfer well to doing so while reading encyclopedia articles.

A second possible explanation for participants' ability to learn to do two tasks at once is that one of the two tasks (for example, the dictation task) is being performed automatically. According to one of Posner and Snyder's (1975) criteria for automaticity—that processing not interfere with other mental activity—taking dictation in this study might be considered automatic. However, participants were clearly aware that words were being dictated, and they typically recognized about 80% of the dictated words on tests immediately following trials. Moreover, participants clearly intended to copy the dictated words. Therefore, taking dictation does not meet Posner and Snyder's last two criteria: lack of intention and lack of conscious awareness.

Hirst et al. (1980) also offered evidence against the possibility that one task becomes automatized. Participants trained to copy complete sentences while reading were able to comprehend and recall those sentences, suggesting that the participants had processed the dictation task for meaning. This in turn suggests they paid at least some attention to the dictation task, given that most psychologists believe automatic processing occurs without comprehension.

A third explanation for how participants were able to perform two tasks at once, which Hirst et al. (1980) favored, is that the participants learned to combine two separate tasks: reading and taking dictation. That is, practice with these two specific tasks caused the participants to perform the tasks differently from the way they did them at first. This implies that if either one of these tasks were combined with a third (such as shadowing prose), additional practice would be needed before the two tasks could be done together efficiently.

Practice thus appears to play an enormous role in performance and is one important determinant of how much attention any task requires. Studies such as those by Hirst et al. are not without critics (see Shiffrin, 1988). However, this work and related studies are beginning to change our understanding of the role that practice plays in cognitive tasks (see Pashler et al., 2001, for a more detailed discussion).

## The Attention Hypothesis of Automatization

Work by Gordon Logan and Joseph Etherton (Logan & Etherton, 1994; Logan, Taylor, & Etherton, 1996) has sought to tie together many concepts we have talked about in this chapter. These researchers propose what they call the **attention hypothesis of automatization,** which states that attention is needed during the practice phase of a task and determines what gets learned during practice. Attention also determines what will be remembered from the practice. Logan et al. (1996) put it this way: “Learning is a side effect of attending: People will learn about the things they attend to and they will not learn much about the things they do not attend to” (p. 620). Specifically, Logan et al. argued that attention affects what information gets encoded into a memory and what information is later retrieved (topics we will take up in detail in Chapters 5 and 6).

In a series of experiments, Logan and Etherton (1994) presented college student participants with a series of two-word displays and asked them to detect particular target words (for example, words that named metals) as fast as possible. For some participants, the word pairs remained constant over trials; for example, if the words *steel* and *Canada* were paired on one trial, then neither word ever appeared with any other word on subsequent trials. Other participants saw word pairs that varied from trial to trial, such as *steel* with *Canada* on one trial and *steel* with *broccoli* on another. The question was, Would participants in the first condition gain an advantage in performance because the words were consistently paired?

The answer was yes, but only when the specifics of the target detection task forced the participants to pay attention to both words in the display. If, for example, the experimenters colored one of the two words green and asked participants only to decide whether the green word in a stimulus display was a target word on each trial, then participants did not gain an advantage from consistent pairings of words and indeed later recalled fewer of the distractor words. Apparently the color cue made it easy for participants to ignore the second word in the display. To ignore something means not to pay attention to it, and thus apparently little gets learned about it. Even with extensive practice (five sessions), participants in the consistent pairing condition were unlikely to learn which words had been paired if they had no reason to pay attention to the distractor word.

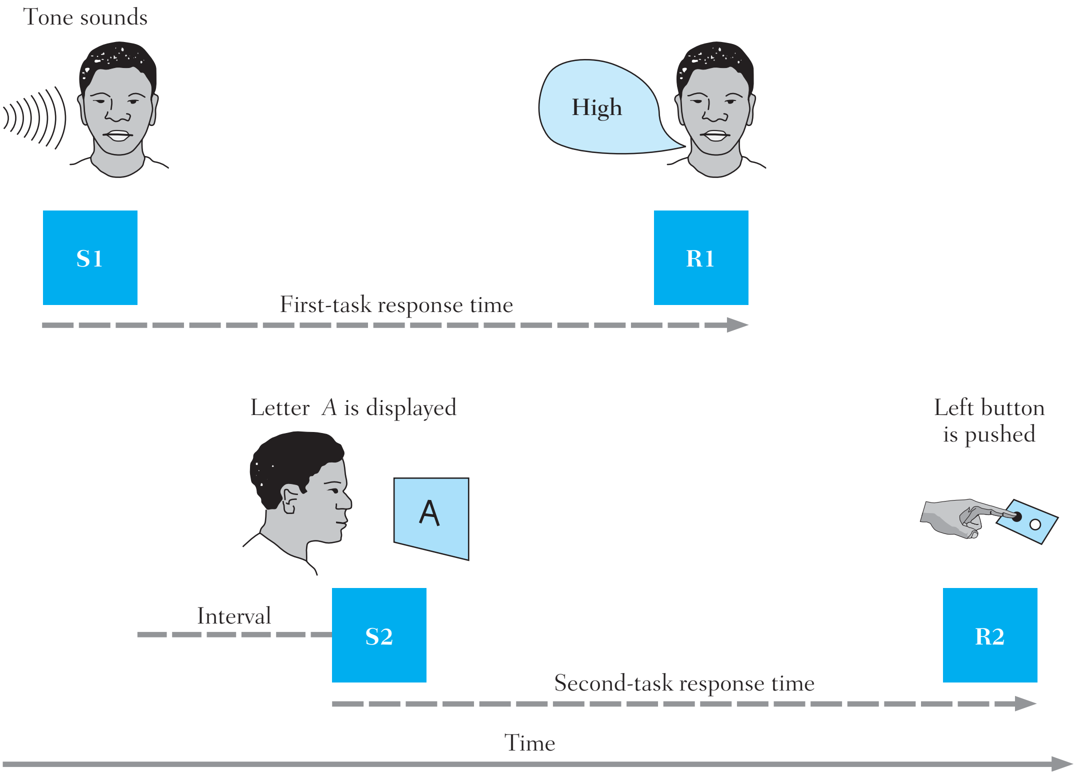
## The Psychological Refractory Period (PRP)

Even with lots of practice, some sets of tasks are hard to do together at the same time. The old child’s hand play of rubbing your stomach while simultaneously patting your head comes to mind. However, it’s fairly easy (if absurd-looking) to pat your own head while carrying on a conversation or singing a song.

Pashler (1993) reported on studies from his and others’ laboratories that examined the issue of doing two things at once in greater depth. The methods used in many such studies are diagrammed in Figure 4-16. The participant is asked to work on two tasks. The first is a tone choice response task, in which on each trial the participant is presented with either a low- or a high-pitched tone and is instructed to respond “low” or “high” as quickly as possible. Reaction times are recorded, and the participant is often given feedback regarding speed

**FIGURE 4-16** ■ *Experiments constructed by cognitive psychologists explore the limits of a subject's ability to perform multiple tasks simultaneously. A typical dual-task experiment is diagrammed here. The subject is presented with one stimulus, labeled S1, to which he is asked to make a specific response, R1. In the case shown, S1 is a tone, which the subject identifies as having a high pitch; his response, therefore, is to say "high." After S1, the subject is presented with a second stimulus, S2, which in this case is a visual display of the letter A. His response, R2, is to press the leftmost of several response keys. The two response times (from S1 to R1 and from S2 to R2) are measured in the experiment. By altering the interval between stimuli or by altering the complexity of either the stimuli or the responses, psychologists have learned a great deal about the mental processes required for dual-task performance.*

**SOURCE:** Pashler (1993, p. 50).



and accuracy. The second task involves visual presentation of a letter, and the participant is instructed to press one of several response keys that correspond to the letter presented.

The interval between the presentation of the tone (S1 in the diagram) and the letter (S2 in the diagram) is systematically varied. At long intervals, participants show no interference and appear to perform the two tasks successively,

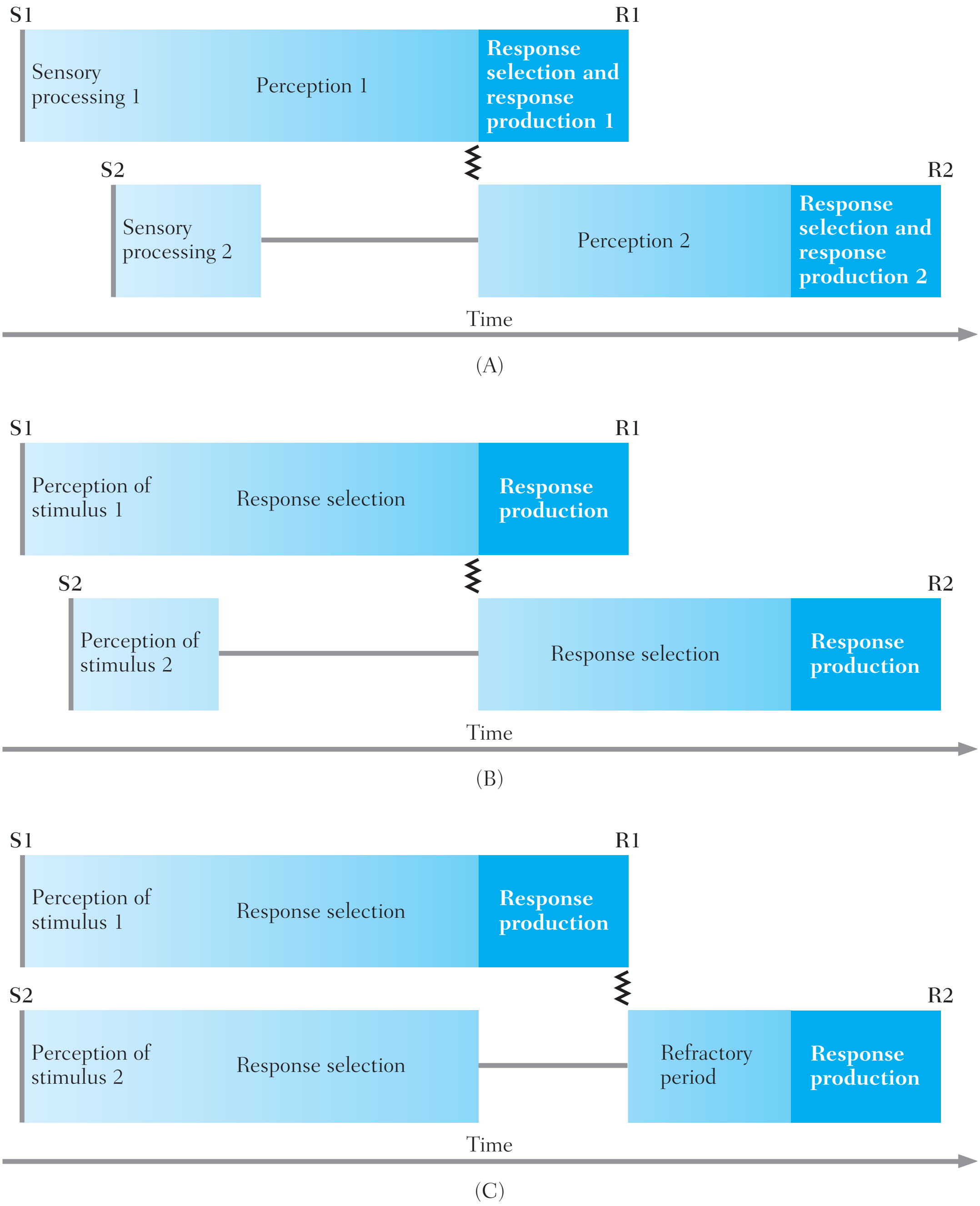
**FIGURE 4-17 (FACING PAGE)** ■ *Bottlenecks could constrict any one of three stages in the performance of a task. If perception of the first stimulus held up further processing, then events would proceed as diagrammed in (A). Here, the subject is potentially capable of processing two stimuli at once but must perceive them one at a time. Hence, the first stimulus must be perceived before the second stimulus can be, but thereafter response selection and production of the first response can proceed while the second stimulus is being perceived. (B) depicts the situation that would arise if response selection caused the bottleneck. In that case, S1 and S2 could be perceived nearly simultaneously, but the second response could not be chosen until the first response selection had been completed. The third possibility, shown in (C), allows both stimulus perception and response selection for the two tasks to proceed simultaneously, but the second response cannot be produced until the first response has been completed. Proponents of this third hypothesis suggest that the motor control system in the brain must "reset" itself after each use and that this limits a person's ability to produce a second response immediately after the first response has been made. Increasing experimental evidence favors the model presented in (B), suggesting that the bottleneck is at the response-selection stage.*

**SOURCE:** Pashler (1993, p. 51).

finishing their response to the first task before beginning to work on the second. However, as the interval between the presentation of S1 and S2 gets shorter and shorter, the time to complete the second task gets longer and longer. The hypothesized explanation is that while the participant is working on the first task, he cannot devote any (or enough) attention to make progress on the second (Johnston, McCann, & Remington, 1995).

Let's pause here to consider an analogy from Pashler (1993). Imagine a bank with one teller and two customers. The amount of time that customer 2 has to wait for the teller depends on the interval between her arrival and that of customer 1. If customer 2 arrives any time after customer 1 has completed her transactions with the teller, then there is no waiting time—the teller's attention is fully available to customer 2. However, if customer 2 arrives while customer 1 is occupying the teller's time, then customer 2 will have to wait until customer 1 is finished. The teller cannot begin to work with customer 2 before he finishes processing all of customer 1's tasks. This waiting time is analogous to the slowed response time to the second stimulus, S2, at short intervals between the presentation of S1 and S2, called the **psychological refractory period,** or **PRP**.

Pashler (1993, 1998) noted that in the banking example, the teller functions as a bottleneck—the limiting factor in the speed with which the second task (customer) gets processed. Coming back to the issue of cognitive processing of two tasks, where is this bottleneck? As Figure 4-17 shows, Pashler considered three distinct possibilities: at the stage of perception of the stimulus (A), at the stage of making a response (C), or at the stage in which a response is selected or chosen (B). In fact, the work of Pashler (1993) and his colleagues supports


S1
R1
Sensory processing 1
Perception 1
Response selection and response production 1
S2
R2
Sensory processing 2
Perception 2
Response selection and response production 2
Time
(A)
S1
R1
Perception of stimulus 1
Response selection
Response production
S2
R2
Perception of stimulus 2
Response selection
Response production
Time
(B)
S1
R1
Perception of stimulus 1
Response selection
Response production
S2
R2
Perception of stimulus 2
Response selection
Refractory period
Response production
Time
(C)

the theory of Welford (1952), who argued for this last possibility (B) and who coined the term *psychological refractory period*. Pashler (1993) also found evidence that retrieving information from memory caused a bottleneck and disrupted attention to the second task. In follow-up work, Pashler and colleagues concluded that the interference does seem to result from a central bottleneck, rather than because a person voluntarily postpones working on one or another of the tasks (Ruthruff, Pashler, & Klassen, 2001).

## Divided Attention Outside the Laboratory: Cell Phone Usage While Driving

Let's see if we can apply some of the theoretical concepts just reviewed to an actual instance of **dual-task performance** in the real world. Recently, many states have enacted or have considered enacting legislation to prohibit drivers from talking on cell phones while behind the wheel. Using a cell phone while driving is becoming more commonplace and is also believed to be a major cause of up to 50% of highway accidents (U.S. Department of Transportation, 1998, as cited in Strayer & Johnston, 2001). The argument against driving while using a cell phone is that talking on a cell phone distracts the driver's attention from what should be the primary task, navigating the vehicle on the road.

Mark Scott/Getty Images

*Driving while talking on a cell phone is often a real-world example of dangerous dual-task performance.*

In a clever simulation, Strayer and Johnston (2001) investigated this interference. In their first experiment, they had research participants perform a pursuit tracking task: They used a joystick to move a cursor on a computer to keep it positioned over a moving target (ethical considerations no doubt precluded doing the study with actual drivers on actual highways!). At various intervals the target flashed either red or green, a signal to the "driver" to push a "brake" button on the joystick (red) or ignore the flash (green). Participants first performed the tracking ("driving") task by itself, then performed the dual-task portion of the study: either listening to a radio broadcast or talking on a cell phone with a confederate of the experimenters. The confederate, who was in a different location, talked with the participants, either about the then-current Clinton presidential impeachment issue or about the Salt Lake City Olympic Committee bribery scandal, and tried to ensure that the participant talked and listened approximately equally. Listening to the radio broadcast did not cause people to miss red lights or to react to them more slowly than they had when they performed the pursuit task by itself (the single-task condition). However, talking on the cell phone did cause both problems, as shown in Figure 4-18.

In a second experiment, the authors had participants talk on a cell phone, either "shadowing" lists of words the confederate read to them or else performing a word-generation task. In the latter task, the participant listened to the word the confederate read (let's say the word was *cream*) and then had to generate a new word that began with the last letter of the word read (in our example, participants had to say a word beginning with the letter *m*). For some participants the pursuit task was easy, with few unpredictable changes, whereas for others it was more difficult, with many such changes. Shadowing words did not lead to reliable decrements in performance. However, generating words did, and the decrement was especially pronounced when the task was difficult.

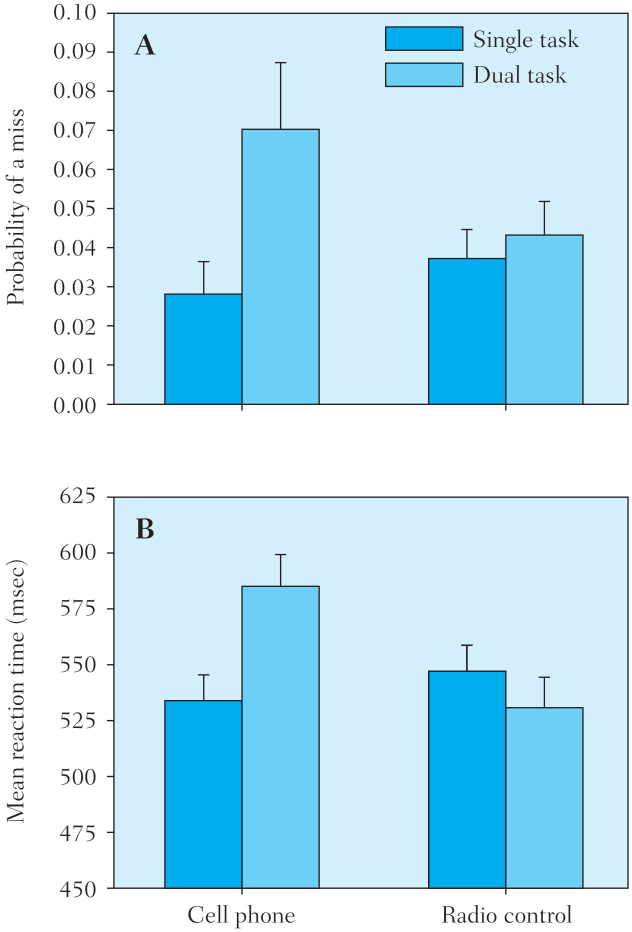
Strayer and Johnston (2001) offered these additional observations:

> It is also interesting to consider the potential differences between cell-phone conversations, and in-person conversations with other occupants of the vehicle . . . there is evidence that in-person conversations are modulated by driving difficulty, so that as the demands of driving increase, participation by all participants in a conversation decreases. . . . By contrast, at least one of the participants in a cellular phone conversation is unaware of the current driving conditions (and may even be unaware that the cell-phone user is driving). (p. 466)

In summary, research on divided attention suggests that there are serious limits on the number of things we can actually do at once. It may seem that we can do things simultaneously in the real world, when in many cases we do both tasks by rapidly switching our attention back and forth between the two. Of course, when those individual tasks become more demanding, it becomes harder and harder to do them simultaneously.

**FIGURE 4-18** ■ *Results from the Strayer and Johnston (2001) study.*

**SOURCE:** Strayer and Johnston (2001, Figure 1, p. 463).



## SUMMARY

The different theoretical approaches to attention surveyed here suggest that psychologists are far from agreeing on how to explain attentional phenomena. Nonetheless, some general themes have emerged.

1. Attention has been shown to be a flexible aspect of cognition. We see that attention, rather than being rigidly and mechanically limited, as first described, is instead a more flexible system, affected by things such as practice, the kinds of tasks being performed, and the person's intention.

2. The idea that there are limits on the number of things we can pay attention to at once is known as *selective attention*. Anecdotal, laboratory, and even neuroscientific evidence seems to suggest that we process information to which we are actively paying attention differently from the way we process information to which we are not attending.
3. Whereas once attention was compared to a bottleneck, today the appropriate metaphor seems to be a spotlight (although some disagree over how far that metaphor extends). The idea here is that attention can vary in effectiveness, just as a spotlight, aimed at one spot, more or less lights surrounding areas, depending on its size and intensity.
4. Cognitive neuropsychologists have identified three different neural (brain) networks of attention, which they have localized in specific regions of the brain. They have also demonstrated a different pattern of event-related potentials for attended and unattended information.
5. Practice with a physical or cognitive task seems to change the amount of attention we need to perform that task. Tasks that require little mental capacity to perform are said to be *automatic*.
6. Some criteria offered to call a task or process "automatic" include the following: (a) It occurs without intention; (b) it occurs without conscious awareness; and (c) it does not interfere with other mental activity. Recently, however, these criteria have been the subject of criticism.
7. It appears that tasks can be performed simultaneously so long as operations such as memory retrieval or response selection are performed serially.
8. A real-world example of the relevance of laboratory research on attention comes from work on conversing via cell phone while driving a car.

## REVIEW QUESTIONS

1. Cognitive psychologists have offered several different definitions of the term *attention*. Which one seems to you the most useful? Describe and defend your criteria.
2. Describe the dichotic listening task, and explain why cognitive psychologists find it a useful way to study attention.
3. Describe the differences and similarities among filter theory, attenuation theory, late-selection theory, and schema theory.
4. Discuss the similarities between change blindness (Chapter 3) and inattentional blindness.
5. Describe and evaluate Kahneman's capacity model of attention. What, if any, real-world phenomena does it predict or explain?

6. What questions are answered by the work on the neurological underpinnings of attention? What questions are raised?
7. Evaluate Posner and Snyder's criteria for what makes a cognitive process automatic. Which criterion is the strongest, and why?
8. Consider the studies on divided attention. Can these findings be used in training workers who need to process a great deal of information from different sources simultaneously? Why or why not?

## Key Terms

- attention hypothesis of automatization
- attentional capture
- attenuation theory
- automatic processing
- controlled processing
- dichotic listening task
- divided attention
- dual-task performance
- event-related potential (ERP)
- feature integration theory
- filter theory
- inattentional blindness
- late-selection theory
- priming
- psychological refractory period (PRP)
- schema theory
- selective attention
- Stroop task

## CogLab Demonstrations

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

If you have access to CogLab, a web-based set of demonstrations in cognitive psychology, you may want to try the **Stroop Effect** demonstration, which will give you some experience of the classic study. You might also try the **Visual Search** demonstration, which will provide experience relevant to the feature integration theory.

## Web Resources

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

## CHAPTER 5

# Forming and Using New Memory Traces

**Metaphors of Memory**

**Sensory Memory**
    The Icon
    The Echo

**Short-Term Memory**
    Capacity
    Coding
    Retention Duration and Forgetting
    Retrieval of Information

**Working Memory**

**Executive Functioning**

**Neurological Studies of Memory Processes**

Many cognitive psychologists regard memory as one of the most basic cognitive processes. We rely on memory whenever we think back to a personal event—when we remember, for example, our first day of school, our 10th birthday, or a trip to Disneyland. Memory is also obviously involved when we remember information about historical events, such as the *Challenger* explosion, the 9/11 attacks, or the sudden death of Diana, Princess of Wales. All these cases illustrate **retrieval,** the calling to mind of previously stored information. The processes by which we do so are the focus of this chapter and the next three chapters.

In one way or another, memory enters into almost every cognitive activity. Clearly, activities such as taking an exam or remembering the name of your third-grade teacher require memory. But other activities, such as balancing a checkbook or comprehending a sentence, also involve some aspect of memory. While doing the calculations necessary to balance a checkbook, we have to keep some numbers in mind, at least for a moment. Similarly, when we hear or read a sentence, we have to keep the beginning of the sentence in mind while we process its middle and end. We use memory so frequently that, as with other cognitive processes, we tend to take it for granted.

Try, for example, to recall your first day at college. What do you remember about that day? Now ask yourself how you are able to recall any of these memories (if in fact you can). If you drew a total blank, why? What exactly goes on when you try to recall? What makes some information memorable and other information hard to recall? (For example, can you describe what your cognitive psychology professor wore two lectures ago?)

Sometimes we fail to notice how extraordinary a particular ability is until we encounter someone who lacks it. Baddeley (1990) has described the tragic case of Clive Wearing, a musician and broadcaster who, because of brain damage caused by encephalitis, has been left with severe amnesia. Although many people suffer from amnesia, Wearing's case is one of the most devastating on record. As Baddeley described it,

> His amnesia was so dense that he could remember nothing from more than a few minutes before, a state that he attributed to having just recovered consciousness. Left to his own devices, he would often be found writing down a time, for example, 3:10, and the note, "I have just recovered consciousness," only to cross out the 3:10 and add 3:15, followed by 3:20, etc. If his wife left the room for a few minutes, when she returned he would greet her with great joy, declaring that he had not seen her for months and asking how long he had been unconscious. Experienced once, such an event could be intriguing and touching, but when it happens repeatedly, day in, day out, it rapidly loses its charm. (pp. 4–5)

Interestingly, a few of Wearing's memory abilities seem to have been spared. He has apparently conducted a choir through a complex piece of music and can still play the harpsichord and piano. These abilities are the exception rather than the rule, however. Wearing cannot go out alone because he would quickly become lost and unable to find his way back. He cannot recognize much in photographs of familiar places, and his memories of his own life are quite sketchy.

In this chapter and the next, I will try to explain these phenomena. To do so, we will look in detail at the processes people use to form, store, and retrieve information. We will examine theoretical approaches to the study of memory, considering memory that lasts only briefly as well as memory that endures for hours, weeks, and even years. Much of the research described in Chapters 5 and 6 comes from the laboratory, where experiment participants, often college student volunteers, are presented with lists or series of words, syllables, or pictures under highly controlled conditions. In some parts of Chapter 6, we will consider how well laboratory-based models apply to memory phenomena outside the laboratory, most often to memories for episodes from people's own life stories.

A brief review of terminology is in order before we begin. We say that **encoding** occurs when information is first translated into a form that other cognitive processes can use. It is held in **storage** in one form or another for later retrieval. We say that **forgetting** occurs when we cannot retrieve information.

## ■ METAPHORS OF MEMORY

Fascination with what memory is and how it works has a long tradition in philosophy, predating any psychological investigations. Neath and Surprenant (2003) noted that the Greek philosopher Plato wrote about memory, comparing it both to an aviary and to a wax tablet on which impressions are made. Throughout the Middle Ages and Renaissance, other analogies were made between memory and a cave, an empty cabinet, and a body in need of exercise.

In the 1950s, memory was compared to a telephone system, and later it was compared to a computer. One theoretical approach to studying memory, which dominated cognitive psychology throughout the 1960s and 1970s, distinguishes among kinds of memory according to the length of time information is stored.

This **modal model of memory,** assumes that information is received, processed, and stored differently for each kind of memory (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965). Unattended information presented very quickly is stored only briefly in **sensory memory.** Attended information is held in **short-term memory (STM)** for periods of up to 20 or 30 seconds. (Synonyms for STM include *primary memory* and *short-term storage,* or *STS*.) Information needed for longer periods of time—the correct spelling of the words on tomorrow's test, for example, or the name of your fourth-grade teacher—is transferred to **long-term memory (LTM),** sometimes called *secondary memory* or *long-term storage* (*LTS*). Figure 5-1 depicts an overview of the modal view of memory. We'll begin our look at psychological investigations of memory using this metaphor, largely because of its enormous influence on the field of cognitive psychology and its ability to make sense of a wide range of memory findings.

Many empirical findings seem to support the idea of different memory systems. One well-known finding comes from free-recall experiments, in which people are given a list of words to remember, such as that shown in Figure 5-2(A), and are asked to recall the words in any order. Next, the experimenter, using data from all the participants, computes the probability of

**FIGURE 5-1** ■ *The modal view of memory. Each box depicts a memory storage system. The arrows represent the transfer of information between systems.*

**SOURCE:** Goldstein (1994, p. 278).

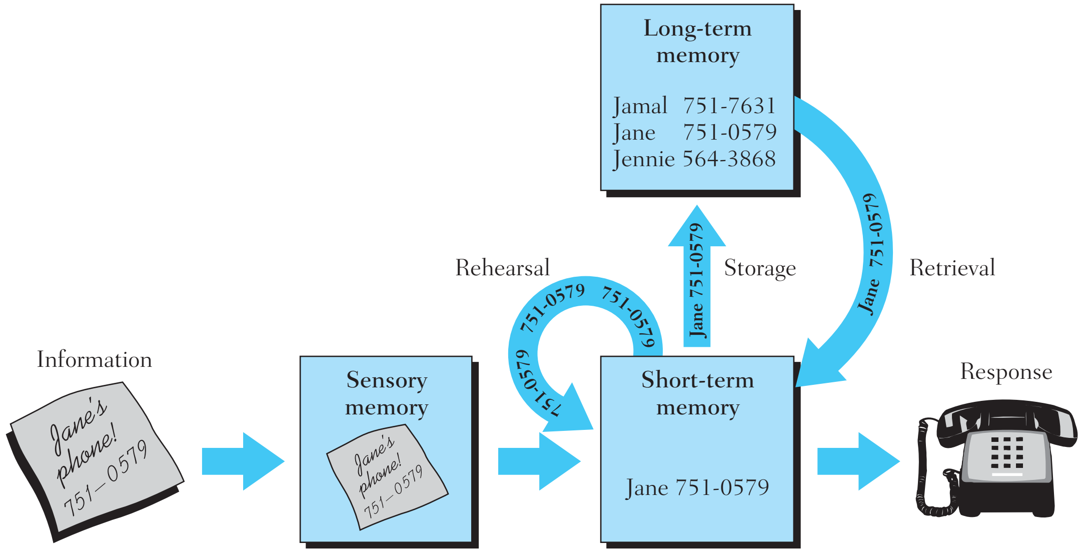
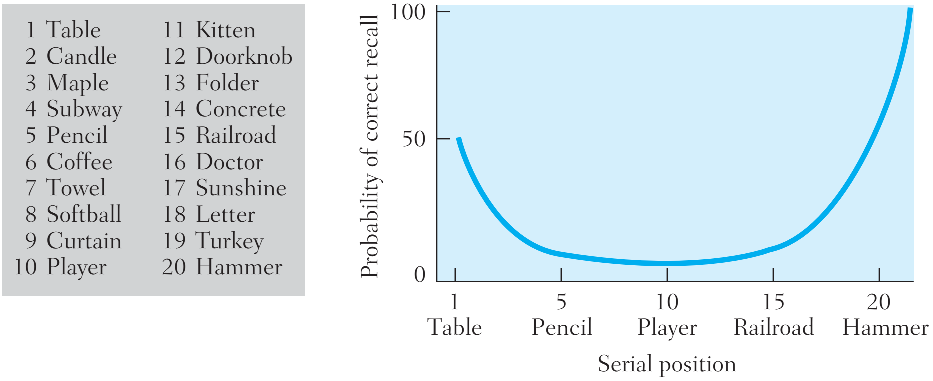

Long-term memory
Jamal 751-7631
Jane 751-0579
Jennie 564-3868
Rehearsal
751-0579 751-0579 751-0579
Jane 751-0579
Storage
Jane 751-0579
Retrieval
Information
Jane's phone! 751–0579
Sensory memory
Jane's phone! 751–0579
Short-term memory
Jane 751-0579
Response

**FIGURE 5-2** ■ *Word list for a serial position curve experiment (A); typical results (B).*



1 Table
2 Candle
3 Maple
4 Subway
5 Pencil
6 Coffee
7 Towel
8 Softball
9 Curtain
10 Player
11 Kitten
12 Doorknob
13 Folder
14 Concrete
15 Railroad
16 Doctor
17 Sunshine
18 Letter
19 Turkey
20 Hammer

(A) (B)

recall of each word as a function of the word's serial position in the original list. In our example, *table* would be in serial position 1 because it is the first word on the list; *candle* is in serial position 2; and so forth. Figure 5-2(B) shows an idealized version of typical results (Murdock, 1962).

Notice that the two ends of the curve are higher than the middle, indicating that people recall more words at either the beginning or the end of the list than they do words in the middle. This is known as the **serial position effect.** The improved recall of words at the beginning of the list is called the **primacy effect;** that at the end of the list, the **recency effect.**

What accounts for these two effects? Participants typically report subvocalizing to themselves as follows when they first start the experiment:

EXPERIMENTER (*reading list at a fixed rate*): Table.

PARTICIPANT (*to self*): Table-table-table-table.

EXPERIMENTER: Candle.

PARTICIPANT (*a little faster*): Table-candle-table-candle.

EXPERIMENTER: Maple.

PARTICIPANT (*very rapidly*): Table-candle-maple-table-candle.

EXPERIMENTER: Subway.

PARTICIPANT (*giving up on rehearsing earlier words*): Subway.

We'll see later that the participant's repetition of items, or **rehearsal,** is thought to help the items enter long-term storage. In fact, if the experimenter reads the list rapidly enough to prevent the participant from having enough time to rehearse, the primacy effect disappears, although the recency effect stays intact (Murdock, 1962).

The recency effect is thought to result from participants' using either sensory memory or short-term memory. Participants often report that they can still "sort of" hear the last few words, and they often report these first and quickly. If the experimenter prevents the participant from reporting words right away, by having her first perform an unrelated counting task, the recency effect (but not the primacy effect) disappears (Postman & Phillips, 1965).

That the primacy and recency effects can be independently affected suggests they reflect two kinds of memory. In addition, some psychologists argue for a third kind of memory, sensory memory, which is thought to work differently from both the other systems. Those who endorse the idea of sensory memory believe that incoming information first passes through this rapidly decaying storage system. If attended to, the information next moves to STM. To be held for longer than a minute or two, the information must be transferred again, this time to LTM.

We will take up the first two hypothesized kinds of memory in this chapter, examining first sensory memory and then STM. After a look at the modal model and its predictions and explanations, we will focus on a newer proposal from psychologist Alan Baddeley, called *working memory.* Next we'll turn our attention to recent proposals for the existence and importance of executive processes that govern and direct the operation of other cognitive processes, picking up on a discussion begun in Chapter 4. This chapter will conclude by looking at both neuropsychological evidence and recent connectionist models, developed on computers, of memory for material actively being processed. We'll defer until Chapter 6 discussion of memories stored over longer periods.

## ■ SENSORY MEMORY

Sensory "memory" is closely connected to what we call "perception." This kind of memory has been described as a record of our percepts (Baddeley, 1990), because it refers to the initial brief storage of sensory information—what you might retain, for example, if you glanced up quickly at a billboard and then glanced quickly away. In fact, there have been debates within cognitive psychology as to whether the findings from a typical sensory memory study are perceptual or memorial (relating to memory) in nature (Neath & Surprenant, 2003), although the more common view today is that the phenomena are in fact more like other memories than they are like other perceptions.

Many cognitive psychologists hypothesize that separate sensory memories exist for each sensory modality. In other words, they believe there is a visual sensory memory, an auditory sensory memory, an olfactory (pertaining to smell) sensory memory, a gustatory (pertaining to taste) sensory memory, and a tactile (pertaining to touch) sensory memory. The overwhelming bulk of the research on sensory memories to date has focused on the first two types of sensory memory, called the *icon* and the *echo,* respectively.

### The Icon

Imagine sitting in a classroom equipped with an overhead projector. The lecturer enters and puts her first transparency on the projector. To check that it is working, she quickly clicks it on and off (she doesn't want to give anyone too much of a sneak preview). If you had been looking at the projection screen when the lecturer clicked the projector on and off, you might have experienced a rapidly fading visual event, and you might have thought it was due to a physical extinguishing of a stimulus—perhaps the bulb in the projector slowly fading. But more carefully controlled studies have demonstrated that the effect is a mental experience (Massaro & Loftus, 1996), as we shall see.

Sperling (1960) conducted an elegant experiment, now considered classic, to investigate the properties of visual sensory memory. He presented participants with displays containing letters, such as shown in Figure 5-3, and asked

**FIGURE 5-3** ■ *Example of the kind of stimulus display used by Sperling (1960).*

**SOURCE:** Sperling (1960, p. 3).

**S D F G**

**P W H J**

**X C V N**

them to recall the letters they saw. The displays were presented briefly, for only 50 milliseconds. Sperling found that, on average, people could report only 4 or 5 of the 12 letters presented. Extending the display time, even to 500 milliseconds, did not improve performance. The problem wasn't perceptual; 500 milliseconds, or half a second, is plenty of time to perceive something about all the letters (Klatzky, 1980).

Sperling (1960) did find a way to improve participants' performance, however, inventing what has become known as the *partial-report technique*. After seeing the display, participants were presented with a low-, medium-, or high-pitched tone. A low pitch indicated they were to report only the letters in the bottom row of the display; a high pitch, those in the top row; and a medium pitch, those in the middle row. Regardless of which tone sounded, participants' reports were almost always completely accurate. This finding suggests participants must have stored the whole display, because they did not know ahead of time which tone would sound. If their accuracy on a randomly chosen row was, say, 90%, we can infer their accuracy for any row would have been 90%. In fact, Sperling found that with the partial-report technique, participants accurately recalled an average of about 3 out of 4 letters in any given row, suggesting an average total recall of about 75% or more.

What caused the better performance? Sperling believed that in the original condition (called the *whole-report condition* because participants had to report the whole display), participants lost the information in their memory during the time they took to report the first few letters. Put another way, even as participants were recalling the display, the information was fading from wherever it was being stored. This implies that information lasts only briefly in this memory system. In fact, Sperling found that if the tone was delayed 1 second, participants giving partial reports did no better than participants giving whole reports.

Neisser (1967) called this brief visual memory the **icon.** The icon is a sensory memory storage system for visual material, holding information for up to about 1 second. The information it holds is in a relatively unprocessed form, as another of Sperling's (1960) experiments showed: If the displays contained both consonants and vowels, and if two different tones cued the participants to report either all the vowels or all the consonants, participants' performance roughly matched their performance when giving whole reports. That indicated that people are not so good at reporting by category (vowel or consonant) as they are at reporting by physical location (e.g., top row, bottom row). Therefore, Sperling inferred, the icon holds information that has not yet been categorized.

Averbach and Coriell (1961) showed that the icon can be "erased" by other stimuli presented immediately after the icon, a phenomenon known as *masking*. For instance, if the display with letters was followed by a display with circles, and if the participant was told to report which letters had been in the locations of the circles, the circles appeared to "erase" the memory trace of the letters originally shown.

Other work investigated how many ways participants could be cued to give partial reports (see Coltheart, 1980, for a review). Different investigators showed that such things as the color or brightness of the letters could be used to cue partial reports. Interestingly, cueing partial reports by category or phonological sound (for instance, "Report all the letters that rhyme with *B*") is all but impossible. This suggests the information available in the icon is only visual—not auditory or related to type of stimulus.

More recent work has complicated the picture of the icon described so far. Neath and Surprenant (2003) reviewed studies that did find evidence research participants could be successfully cued to report by category. They also described other studies showing that although information for the particular location in the matrix fades over time, information about *which* letters were presented does not seem to. As a result, some cognitive psychologists are now coming to view the icon as a mental representation lasting only about 150 to 200 milliseconds, followed by a recoding of the stimulus into another, more meaningful code.

## The Echo

There is also a sensory memory for auditory material, which Neisser (1967) called the **echo.** Moray, Bates, and Barnett (1965) offered a clever demonstration of the echo. Participants were given a "four-eared" listening task, similar to a dichotic listening task (see Chapter 4 if you've forgotten what this is). They heard, simultaneously over headphones, four channels of incoming information, each apparently coming from a different location, consisting of a string of random letters. (The four channels were created by stereophonic mixing.)

In one condition, similar to Sperling's (1960) whole-report condition, participants were asked to report all the letters they had heard. In another condition, each participant held a board with four lights on it, each light corresponding to one of the channels, cueing the participant to report only the letters from a particular channel. As did Sperling, Moray et al. found that participants giving partial reports could report proportionately more letters. This suggests that the echo, like the icon, stores information only briefly.

Darwin, Turvey, and Crowder (1972) later replicated Moray et al.'s result, using better experimental controls, although they found a much smaller partial-report advantage. Darwin et al. also found that recall could be cued by category, at least to some degree, suggesting that the echo works somewhat differently from the icon. Crowder (1976), reviewing the literature on echoic memory, proposed that echoic memory has a larger capacity than iconic memory. Other investigations (Watkins & Watkins, 1980) provided evidence that echoes can last longer than icons, perhaps even as long as 20 seconds, although other researchers disagree with these conclusions (Massaro & Loftus, 1996).

A demonstration called the "suffix effect" also reveals something about the nature of echoic memory. Imagine you are a research participant in a memory experiment, and a list of random digits, letters, or the like is being presented to you. If the list is presented to you auditorily (as opposed to visually), and if there is an auditory recall cue such as a spoken word or specific item, recall of the last few items on the list is seriously hindered (Crowder, 1972).

Researchers think the recall cue, called the *suffix,* functions as an auditory "mask" of sorts, because when the suffix is simply a beep or tone, or a visual stimulus, there is usually not much effect. Nor is there any effect if the items on the list are presented visually—say, on a computer screen. Finally, the more auditory similarity there is between the suffix and the items on the list, the greater the suffix effect.

Although research continues to refine our understanding of both the icon and the echo, sensory memory can currently best be described by a number of properties. First, sensory memories are *modality specific:* the visual sensory memory contains visual information; the auditory sensory memory, auditory information; and so forth. Second, sensory memory capacities appear relatively large, but the length of time information can be stored is quite short, much less than a second. Third, the information that can be stored appears relatively unprocessed, meaning that most of it has to do with physical aspects of the stimuli rather than with meaningful ones.

Some proposals (Haber, 1983; Neisser, 1983) have disputed the idea that the icon and the echo play a necessary role in perception or memory. Although no one disputes the findings reported by Sperling (1960) and others, some argue that problems arise with the interpretations of the findings. In particular, some researchers assert that the very brief (typically less than a second) presentation of stimuli created an artificial task for participants, unlike anything people would need or want to do outside the laboratory. In contrast, Neath and Surprenant (2003) argued that sensory memory research could have a very practical use outside the laboratory: Having directory assistance operators say "Have a nice day" after giving a phone number should (and apparently does) disrupt recall for the phone number because their pleasant sign-off acts as a suffix!

Another counterargument to the idea that sensory memory is only a laboratory phenomenon is that sensory memory guarantees a minimum of time during which information presented to us (that we pay attention to) is available for processing (Baddeley, 1990). In other words, by this argument sensory memory *does* play an important role in the everyday workings of normal memory: It ensures that we will be able to "reinspect" incoming data, if not with our actual eyes and ears, then with the mind's eye and the mind's ear. As you can see, then, the role that sensory memory plays in later processing of information is very much debated.

Lambert/Getty Images

*Research on the echo suggests that telephone operators who wish callers a nice day may inadvertently be disrupting their auditory sensory memory of the phone number they've just provided.*

## SHORT-TERM MEMORY

Most of the time, when people think about memory they think about holding onto information for longer than a second or two. In the rest of this chapter and the next, we'll talk about kinds of memory more familiar to nonpsychologists.

We'll first look at STM. You use this kind of memory system when you look up a phone number, walk across a room to a telephone, and dial the number. Suppose I asked you to call one of my colleagues, whose phone number is 555-4362. Suppose further that you couldn't take this book with you but had to remember the number until you could dial it on a nearby phone. How would you accomplish this task? Chances are you'd begin by rehearsing the number aloud several times as you walked across the room. You'd dial the number, but as soon as the conversation started, you'd be likely to have forgotten the number you dialed. This example illustrates one aspect of STM: It lasts only a short while. (Cognitive psychologists typically regard STM as lasting for a minute or two, if rehearsal is not prevented; however, neuropsychologists sometimes consider information in STM as lasting for up to a day, which can lead to some confusion. When I talk about STM, I'll be talking about material stored for up to about a minute.)

Does any other distinguishing characteristic separate STM from LTM, other than length of time information is stored? Psychologists who make the distinction believe there are a number of such characteristics, including how much information can be stored (capacity), the form in which the information is stored (coding), the ways in which information is retained or forgotten, and the ways in which information is retrieved. How psychologists working within the information-processing paradigm conceptualize STM has changed a great deal over the past two decades. We'll begin with a look at the traditional description of STM before looking at a newer proposal of what has been renamed *working memory* to avoid confusion.

### Capacity

If you are going to store information for only a short period of time (as in the phone number example), how much room do you have in which to do so? In other words, how much information can you remember for only a brief period of time? A classic paper by George Miller (1956) begins with the following rather unusual confession addressing these questions:

> My problem is that I have been persecuted by an integer. For seven years this number has followed me around, has intruded in my most private data, and has assaulted me from the pages of our most public journals. This number assumes a variety of disguises, being sometimes a little larger and sometimes a little smaller than usual, but never changing so much as to be unrecognizable.

> The persistence with which this number plagues me is far more than a random accident. There is, to quote a famous senator, a design behind it, some pattern governing its appearances. Either there really is something unusual about the number or else I am suffering from delusions of persecution. (p. 81)

The integer plaguing Miller was 7 (plus or minus 2). Among other things, 7 (plus or minus 2, depending on the individual, the material, and other situational factors) seems to be the maximum number of independent units we can hold in STM. We call this the **capacity** of STM.

Miller (1956) reviewed evidence demonstrating that if you are presented with a string of random digits, you'll be able to recall them only if the string contains about seven or fewer digits. The same is true if you are presented with random strings of any kinds of units: letters, words, abbreviations, and so on. The only way to overcome this limitation is by somehow **chunking** the individual units into larger units. For instance, consider the following string of letters: *N F L C B S F B I M T V*. This 12-letter string would normally exceed almost everyone's short-term memory capacity. But if you look closely at the letters, you'll see they really form four sets of abbreviations for well-known entities: *NFL* (the National Football League), *CBS* (one of the three major television networks currently operating in the United States), *FBI* (the Federal Bureau of Investigation), and *MTV* (the rock video cable television station). If you notice that the 12 letters are really four organized sets, you'll be more likely to recall the entire string. In recognizing that the three sets of letters really "go together" and in forming them into a single unit, you are said to be chunking them.

Chunking depends on knowledge. Someone not familiar with our culture might regard *MTV* as merely three randomly presented letters. Miller regarded the process of forming chunks (he called it "recoding") as a fundamental process of memory—a very powerful means of increasing the amount of information we can process at any given time, and one we use constantly in our daily lives. The process of chunking can be seen as an important strategy in overcoming the severe limitation of having only seven or so slots in which to temporarily store information.

## Coding

The term **coding** refers to the way in which information is mentally represented—that is, the form in which the information is held. When you try to remember a phone number, as in the preceding example, how do you represent it? A study by R. Conrad (1964) addressed this question. He presented participants with lists of consonants for later recall. Although the letters were presented visually, participants were likely to make errors that were similar in *sound* to the original stimuli. So, if a *P* had been presented, and participants later misrecalled this stimulus, they were much more likely to report a letter that *sounded* like *P* (for example, *G* or *C*) than to report a letter that *looked* like *P* (such as *F*). Remember, the original presentation was visual, but participants apparently were confused by the sound. Participants were apparently forming a mental representation of the stimuli that involved acoustic rather than the visual properties.

Later work by Baddeley (1966a, 1966b) confirmed this effect even when the stimuli were words rather than letters: Similar-sounding words make for poor immediate recall, although similar-meaning words don't, and the reverse is true for delayed recall. Although an acoustic code is not the only one used in STM, researchers have regarded it as the dominant code used, at least by hearing adults and older children (Neath & Surprenant, 2003).

## Retention Duration and Forgetting

We regard STM as the storage of information for short periods of time. But how short is short? John Brown (1958) and Peterson and Peterson (1959), working independently, came to the same conclusion: If not rehearsed, information is lost from STM in as little as 20 seconds. That length of time is called the **retention duration** of the memory.

The Brown–Peterson task works as follows. Participants are presented with a three-consonant trigram, such as *BKG*. They are also given a number, such as 347, and asked to count backward out loud by threes, at the rate of two counts per second, in time to a metronome. The purpose of the counting task is to prevent the participant from rehearsing the trigram. The length of time a participant must count varies. If asked to count backward for only 3 seconds, roughly 80% of participants can recall the trigram. If asked to count for 18 seconds, this drops to about 7%. Both Brown and the Petersons interpreted this finding as meaning that the **memory trace**—the encoded mental representation of the to-be-remembered information that is not rehearsed—**decays,** or breaks apart, within about 20 seconds. Putting this interpretation into our phone number example gives us the following: If I tell you my phone number, and you fail to do something to remember it (say, by rehearsing it or writing it down), you'll be able to remember it only for a maximum of about 30 seconds. After that time, the memory trace will simply decay, and the information will be lost.

However, other cognitive psychologists soon began to challenge this decay explanation of forgetting. They proposed a different mechanism, called **interference,** that worked as follows: Some information can "displace" other information, making the former hard to retrieve. You can think of the interference explanation as being akin to finding a piece of paper on my desk. At the start of each academic term, my desk is (relatively) free of clutter. Any piece of paper placed on the desktop is trivially easy to find. However, as the term goes on and my time grows short, I tend to allow all kinds of memos, papers, journals, and

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*A photo of my desk, representing the idea of memorial interference.*

the like to accumulate. Papers placed on my desk at the beginning of the term become buried; they're there, all right, but can be very difficult to find at any given moment. The late-arriving papers have "displaced" the early papers.

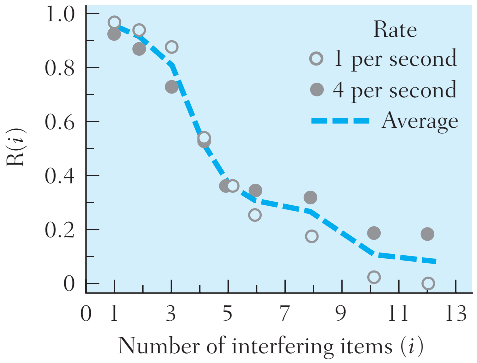
Can we explain the Brown–Peterson task results in terms of interference? Think once again about the counting task. Notice that it supposedly has very little purpose other than to distract the participant from rehearsing the trigram. Yet maybe the counting task does more than prevent participants from rehearsing; it may actually interfere with their short-term storage of the trigram. As participants count aloud, they compute and announce the values. As they compute and announce the values, they put them into STM. Thus the counted values may actually be displacing the original information.

A study by Waugh and Norman (1965) demonstrated the role of interference in STM. They invented the *probe digit task,* which works as follows. Participants are given a 16-digit number, such as 1596234789024815. The last digit in the number is a cue for the participant to report the number that first came after the first occurrence of the cue in the number. (It's a little complicated to follow that instruction, but it can be done; stop reading for a moment and actually try it.) In our example, the cue is 5 (it's the last digit of the number), and the first occurrence of 5 in the number is followed by a 9, so the response should be 9.

Waugh and Norman (1965) presented the numbers either quickly, at the rate of four digits per second, or slowly, at the rate of one digit per second. Their reasoning was that if decay caused forgetting in STM, then participants receiving a slow rate of presentation should be not as good at recalling digits from early in the number. This is because more time would have elapsed on trials with the slow presentation, causing more decay from the beginning of the number. Figure 5-4 (which plots the rate of recall as a function of the number of interfering items) shows, however, that this is not what happened. Participants showed equivalent performance on recalling digits throughout the number regardless of rate of presentation. On all trials, participants were not as good at recalling digits from early in the number as from later in the number, implicating interference rather than decay in forgetting information in STM.

**FIGURE 5-4** ■ *Results from Waugh and Norman's (1965) probe digit task study.*

**SOURCE:** Waugh and Norman (1965, p. 91).



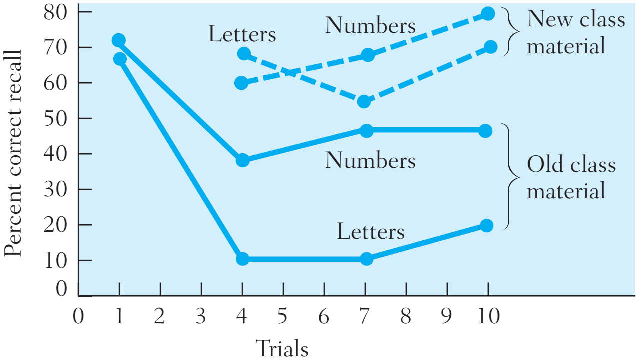
Other evidence also supported the view that interference, not decay, accounts for forgetting in STM. Keppel and Underwood (1962), for instance, found that forgetting in the Brown–Peterson task doesn't happen until after a few trials. They suggested that over time, **proactive interference** builds up. This term refers to the fact that material learned first can disrupt retention of subsequently learned material. (We'll discuss this phenomenon in greater detail in Chapter 6.) Keppel and Underwood showed that even one trial's worth of practice recalling a three-letter trigram was enough to hurt subsequent memory for other trigrams.

Wickens, Born, and Allen (1963) extended the idea one more step. They reasoned as follows: If STM, like LTM, is subject to proactive interference, then STM, like LTM, should also be subject to a related phenomenon, *release from proactive interference*. In other words, if you learn a number of pieces of similar information, after a while any new learning becomes more difficult because the old learning interferes with the retention of new (because of proactive interference). The greater the similarity among the pieces of information, the greater the interference. This implies that if a new and very distinct piece of information were presented, the degree of interference would be sharply reduced.

Wickens et al. (1963) demonstrated release from proactive interference in a clever experiment. They gave participants a series of either three-digit strings (such as *179*) or three-letter strings (such as *DKQ*). There were 10 trials in all. Some participants received 10 trials of the same type (that is, all-letter strings or all-digit strings). Others saw a "switch" in the stimuli partway through the 10 trials. For example, a person might see 3 trials with letters but then be switched to seeing digits on all subsequent trials. Figure 5-5 shows the results. Participants getting a "switch" performed almost as well immediately after the switch as they did on the first trial. Their memory is said to have been released, or freed, from the clutches of proactive interference!

**FIGURE 5-5 ■** *Results from the Wickens et al. (1963) study on release from proactive interference in short-term memory.*

**SOURCE:** Wickens et al. (1963, p. 442).



All this evidence might lead you to think all cognitive psychologists agree that only interference causes forgetting in STM. The picture, however, is not that neat. Reitman (1971, 1974) initially offered evidence supporting an interference explanation of forgetting in STM. Her participants performed a Brown–Peterson task while simultaneously working on what was supposed to be a noninterfering task: detecting a syllable such as "doh" in a spoken stream of repetitions of a similar syllable (“toh”). The auditory detection task was supposed to prevent participants from rehearsing the trigram but not to interfere with material stored in STM. An interference account of forgetting in STM would predict no loss of the trigrams over the retention periods, and this is indeed what Reitman (1971) found. However, in an important follow-up, Reitman (1974) found that some of her participants confessed to “cheating” a bit: surreptitiously rehearsing the letters while they performed the detection task. When Reitman looked only at the performance of the participants who hadn’t been rehearsing, she found clear effects of decay: Only 65% of the trigrams were retained after a 15-second interval. From this, Reitman concluded that information really could decay if not rehearsed in STM.

Reitman’s research leaves us with an unresolved issue: What causes forgetting in STM, trace decay or interference? We cannot rule out either one, at least for now. One problem is that it is hard to think of a task in which no interference can occur. Thus, designing a definitive experiment (or series of definitive experiments) is beyond our current capabilities.

Also, maybe the question “Is it decay or is it interference?” is badly posed, because it rules out the possibility that both may be involved. That is, maybe STM loses information by more than one mechanism. Either/or questions exclude this possibility. Baddeley (1990) argues that some (although very little) trace decay does occur in STM along with interference. Altmann and Gray (2002) propose that decay does occur and in fact is essential to avoid catastrophic proactive interference. These authors believe that when information must be updated frequently in memory (example: you are driving and have to remember the speed limit on each new road you take), its current value (you’re on an interstate, going 70 mph) decays to prevent interference with later values (you get off the highway, and the speed limit is now 55 mph).

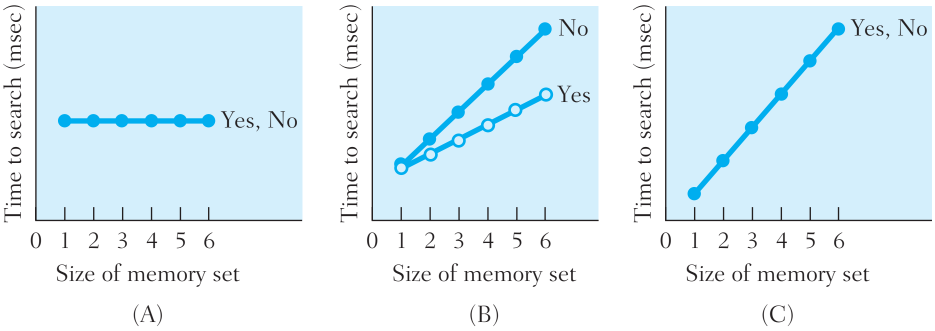
## Retrieval of Information

We’ve talked about the ways in which people hold onto information for brief periods of time: how they encode it, how much they can encode, and how long they can retain it. That brings us to the question “How do we retrieve this information from STM when we need it again?” Saul Sternberg (1966, 1969), in a series of experiments, found some surprising things about how we retrieve information from short-term memory. Before turning to his experiments, let’s consider various possibilities of how information might be retrieved from STM.

Sternberg’s first question was whether we search for information held in STM in a *parallel* or a *serial* manner. Imagine, for example, that STM is full of some (small) number of movie titles. Let’s say STM holds a list of my all-time favorite movies, which I have just orally given you. Let's call the number of movie titles the *memory set size.* Now suppose that someone asks you if *Titanic* is on that list and that to answer the question, you mentally search the list.

If you compare *Titanic* simultaneously to all the titles on your list, you are performing a **parallel search.** Essentially, no matter what the number of titles is, you examine them at the same time, and it takes you no more time to compare *Titanic* to 1 title than to 10 titles. Figure 5-6(A) depicts how the data would look if you used parallel search, plotting time to search against memory set size.

**FIGURE 5-6** ■ *Theoretically predicted results from the Sternberg (1966) short-term memory-scanning experiment. "Yes" and "No" refer to whether the subject will report finding the probe letter in the memory set. (A) depicts a parallel search; (B), a serial, self-terminating search; (C), a serial, exhaustive search. The data that Sternberg reported looked most like those in (C).*



Suppose, instead, that you use a **serial search.** In our movie titles example, this would mean comparing *Titanic* to the first movie title on the list, then to the second title on the list, and so on, until you come to the last title. The comparisons are done one at a time. In this model, the longer the list is, the longer it should take to decide if *Titanic* matches a title on that list. Successful searches are indicated by the "yes" line; unsuccessful searchers (where a target is not found) by the "no" line.

We can also ask whether the search is self-terminating or exhaustive. A **self-terminating search** stops when a match is found. Suppose the list of movie titles is *Shopgirl, Memento, Titanic,* and *Jarhead.* If you do a self-terminating search, you will stop after the third comparison because you've found a match. On average, then, successful searches take less time (because you don't continue searching after you've found the match) than unsuccessful searches (where you have to search through everything). Figure 5-6(B) depicts the results we should see if retrieval from memory uses serial, self-terminating search.

Another kind of serial search is an **exhaustive search,** meaning that even if a match is found, you continue looking through every other item in the set. In our example, this would mean that even after you find *Titanic,* you check the remaining titles on the list. With this kind of search, it takes just as long for successful as for unsuccessful searches. Figure 5-6(C) shows this possibility.

Sternberg's (1966) experimental task was the following. First, participants were presented with a set of seven or fewer letters. These were to be encoded and held in short-term memory and hence could be called the "memory set." After the participant had the set in memory, he indicated readiness for an upcoming trial. A single letter, called a probe, was presented, and the participant's task was to decide, as quickly as possible, whether the probe was in the memory set. For example, the memory set might be *B K F Q,* and probes might be *K* (yes, in the memory set) and *D* (no, not in the memory set).

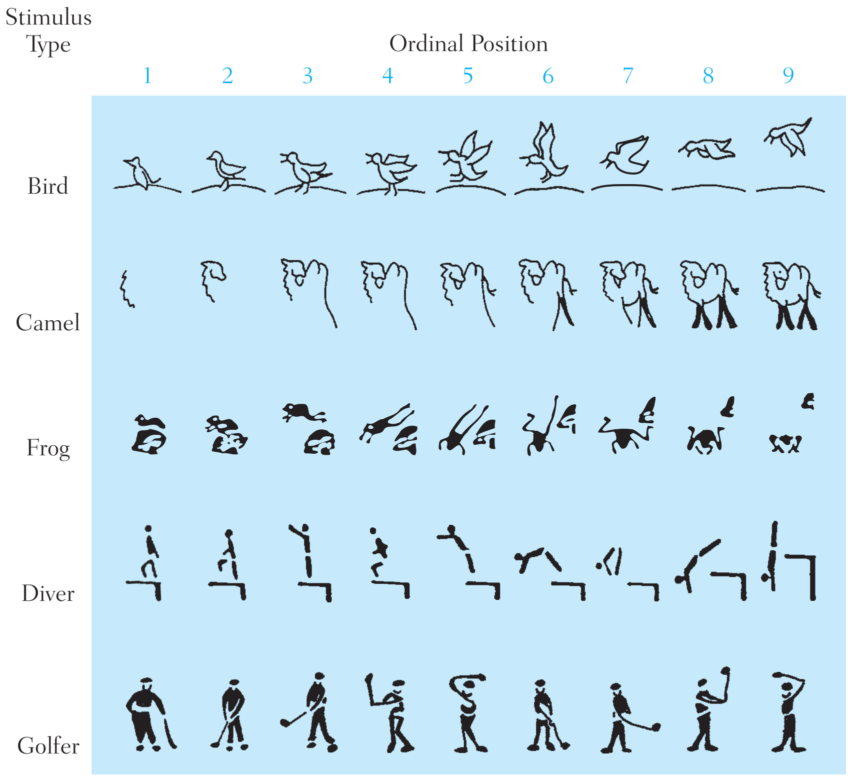
As counterintuitive as it sounds, Sternberg's (1966) results argue for serial, exhaustive search as the way we retrieve information from STM. Sternberg's explanation is that the search process itself may be so rapid and have such momentum it is hard to stop once it starts. From a processing point of view, it may be more efficient just to let the search process finish and then make one decision at the end, instead of making several decisions, one after each item in the memory set. A review by Hunt (1978) found that people of all sorts (college students, senior citizens, people with exceptionally good memories, retarded people) showed results consistent with the idea that retrieval from STM uses serial, exhaustive search, although search rate changes with the group, being faster for people with exceptional memories and slower for senior citizens.

As with just about any scientific proposal, later work by other investigators turned up problems with Sternberg's (1966, 1969) proposal of serial, exhaustive search. Baddeley (1976) reviewed some of the problems and alternative explanations of Sternberg's findings. An intriguing twist on the Sternberg study comes from DeRosa and Tkacz (1976), who demonstrated that with certain kinds of stimuli, such as those shown in Figure 5-7, people apparently search STM in a parallel way.

Note that the stimuli DeRosa and Tkacz used consisted of ordered sequences of pictures, such as pictures of a golfer executing a golf swing. If on the one hand the memory set consisted of some randomly selected subset of the nine pictures—for example, pictures 1, 4, 6, 8, and 9—from any of the sets, then the results looked like the typical Sternberg results. On the other hand, if the memory set consisted of an ordered subset of the original sequence—for instance, pictures 2, 3, 4, 5, and 6—then it took participants no longer to search through five items than it did through two. Interestingly, it didn't matter whether the ordered subset was presented in order (for example, picture 2, then picture 3, then picture 4, and so on) or not in order (say, picture 5, then picture 2, then picture 6, and so on); participants still apparently performed a parallel search.

**FIGURE 5-7** ■ *Stimuli used by DeRosa and Tkacz (1976).*

**SOURCE:** DeRosa and Tkacz (1976, p. 690).



This work suggests that STM treats ordered, organized material differently from unorganized material. Just as the chunking of digits or letters into more coherent patterns changes the apparent capacity of STM, using organized material also apparently affects the way it is processed.

This study makes an important point: Memory processes apparently work differently as a function of the material (stimuli) to be remembered. Therefore, we cannot automatically generalize results from the laboratory to everyday life. Instead, to know which laboratory models bear on which kinds of phenomena we need to consider what kinds of information are processed in what ways.

Let's summarize our review of the STM system so far. The general picture that emerged in the 1960s and 1970s was that STM is a short-term, limited-capacity storehouse where information is coded acoustically and maintained through rehearsal. Information can be retrieved from this storage using high-speed, serial, exhaustive search. The nature of the information in STM, however, can help change the capacity and processing of stored information.

## WORKING MEMORY

The idea that memory consists of a number of information-processing stores was most completely described by Atkinson and Shiffrin (1968). These authors distinguished between the information being stored, calling this "memory" (for example, STM, LTM), and the structure that did the storing, which they termed a "store" (for example, STS, LTS). Their conception of STS was that it does more than merely hold onto seven or fewer pieces of information for a few seconds. In addition, they thought, information in STS somehow activates relevant information from LTS, the long-term store, and gathers some of that information into STS. They equated STS with consciousness and saw it as the location of various *control processes* that govern the flow of information, such as rehearsal, coding, integration, and decision making. STS is involved in transferring information to LTS, in integrating various pieces of information, and in keeping certain information available.

Baddeley and Hitch (1974) performed a series of experiments to test this model. The general design was to have participants temporarily store a number of digits (thus absorbing some of the STS storage capacity) while simultaneously performing another task, such as reasoning or language comprehension. These tasks were also thought to require resources from STS—specifically, the control processes mentioned earlier. The hypothesis was that if the STS capacity is taken up by stored digits, fewer resources are available for other tasks, so performance on other tasks suffers.

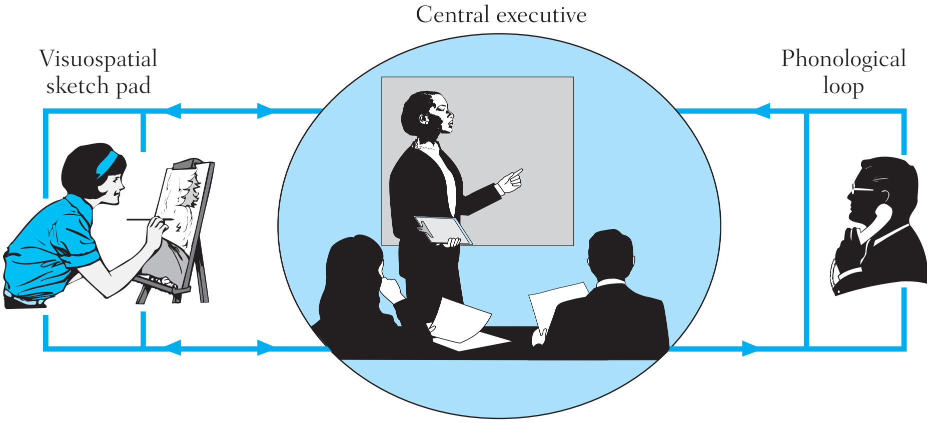
Let's look at one of Baddeley and Hitch's studies in detail. Participants saw a sentence describing the order of appearance of two letters—for example, "*A* is preceded by *B*"—together with two letters in a particular order—for example, "*B A*." The task was to decide, as quickly as possible, if the sentence correctly described the two letters. Participants were given from one to six digits to hold in memory while they verified the sentences. The results showed that participants were able to verify the sentences while holding one or two digits in memory about as well as they could without holding any digits in memory. However, a six-digit memory load did hurt performance: The sentence took longer to verify. The effect was especially pronounced if the sentence was negative and passive (for example, "*B* is not preceded by *A*"), both of which properties are known to be harder to process. Although performance was hurt by storing six digits, the effects were not catastrophic (Baddeley, 1990). That is, it took people much longer to reason while rehearsing six digits, but they still could perform the task. According to the predictions from Atkinson and Shiffrin's (1968) model, they should not have been able to do so. Related experiments showed that storing digits in memory also interfered with reading comprehension and the recall of recently learned material.

Baddeley and Hitch (1974) and Baddeley (1981) interpreted the findings from the various studies as follows. First, a common system does seem to contribute to cognitive processes such as temporarily storing information, reasoning, and comprehending language. Filling up STM with six digits does hurt performance on a variety of cognitive tasks, suggesting that this system is used in these tasks. However, the memory loads used, thought to be near the limit of STM capacity, do not totally disrupt performance. Because researchers think STM has a capacity of about seven items, plus or minus two, the six-digit memory load should have essentially stopped any other cognitive activity. Baddeley and Hitch (1974) therefore argued for the existence of what they called **working memory (WM).** They see WM as consisting of a limited-capacity "workspace" that can be divided between storage and control processing.

Baddeley (1981, 1986, 1990) conceived of WM as consisting of three components, as depicted in Figure 5-8. The first is the **central executive.** This component directs the flow of information, choosing which information will be operated on when and how. Researchers assume it has a limited amount of resources and capacity to carry out its tasks. Some of this capacity can be used to store information. The central executive is thought to function more as an attentional system than a memory store (Baddeley, 1990), meaning that rather than dealing with the storage and retrieval of information, the central executive deals with the way resources are allocated to cognitive tasks. So the central executive would be the system that controls many of the phenomena reviewed in Chapter 4. The central executive is also thought to coordinate information coming from the current environment with the retrieval of information about

**FIGURE 5-8** ■ *Baddeley's (1990) model of working memory.*

**SOURCE:** Adapted from Baddeley (1990).



the past, enabling people use this information to select options or form strategies. Baddeley (1993a) equated this coordination with conscious awareness.

The two other components of Baddeley's model are concerned with the storage and temporary maintenance of information: the **phonological loop,** used to carry out subvocal rehearsal to maintain verbal material, and the **visuospatial sketch pad,** used to maintain visual material through visualization. Researchers think the phonological loop plays an important role in such tasks as learning to read, comprehending language, and acquiring vocabulary. The visuospatial sketch pad involves the creation and use of mental images.

Notice that postulating the existence of a separate phonological loop explains why having a person remember digits (which presumably loads the phonological loop) does not totally devastate performance on other tasks requiring WM. Researchers think this is so because the tasks spared are drawing on another part of working memory. Investigators think the phonological loop consists of two structures: a short-term phonological buffer (which holds onto verbal information for short periods of time, such as a few minutes, assuming rehearsal is not prevented), and a subvocal rehearsal loop used to compensate for the rapid decay of information in the phonological buffer (Demetriou, Christou, Spanoudis, & Platsidou, 2002). The idea here is that when the person initially encounters information, particularly verbal information, she translates it into some sort of auditory code and processes it through the phonological loop. Because the information from the phonological buffer decays rapidly, the person must subvocally rehearse the information, and the faster the rehearsal process, the more information can be maintained. If the phonological buffer is "filled up"—say, by having a person repeat a syllable or count aloud—then less capacity from this system is available to devote to other tasks.

Researchers have devised various working-memory-span tasks involving the phonological loop. A very well known one, created by Daneman and Carpenter (1980), works like this: A person is given a set of sentences to read (usually aloud)—but at the same time is asked to remember the last word in each sentence for later recall. For example, the participant might be presented with the following three sentences:

> The leaves on the trees turn various hues in autumn.
>
> A group of students congregated outside the front entrance of the delicatessen.
>
> Although lying and fabrication are generally not acceptable, they are sometimes necessary.

After reading them aloud, the participant is cued to recall the last word in each sentence. In this example, the correct answers are *autumn, delicatessen,* and *necessary.* The number of sentences a participant can process and reliably recall words from is said to be a measure of his span. This measure has been shown to correlate significantly with other cognitive measures, such as reading comprehension and other complex cognitive tasks (Miyake, 2001).

The visuospatial sketch pad is to visual material as the phonological loop is to auditory and/or verbal material: Researchers think it maintains and is involved in the manipulation of visual information and imagery (Baddeley & Andrade, 2000). We will be taking up the topic of visual imagery in Chapter 9, and so will defer a detailed discussion until then.

Teasdale et al. (1995) reported an interesting application of Baddeley's conception of working memory. They focused on stimulus-independent thoughts (SITs), which they defined as "a flow of thought or images, the contents of which are quite unrelated to immediate sensory input" (p. 551). SITs include things such as daydreams or even intrusive thoughts such as when we worry or ruminate over a problem or concern.

Teasdale et al. (1995) questioned whether the production of SITs could be disrupted by having research participants perform another task. Some of the tasks they had their participants perform were verbal and were thought to involve the phonological loop of working memory. An example is the "silly sentences" task, in which people view a sentence (such as "Bishops can be bought in shops") and judge as quickly as possible whether each sentence is true or false. Other tasks were more visual or spatial. For example, people viewed complex drawings and were asked to find "hidden" geometric figures or to tap different keys on a keyboard in a particular manner.

During the experimental sessions, participants were stopped at different points and asked to tell the experimenter "exactly what was passing through [their] mind when [they] heard the experimenter say 'stop.'" Experimenters transcribed and later categorized these thoughts as to whether they pertained to the task at hand or were unrelated to it (that is, were SITs). Teasdale et al. (1995) found that both the auditory and the visuospatial tasks significantly disrupted SIT production. Thus neither the phonological loop nor the visuospatial sketch pad is solely responsible for SITs production.

In subsequent experiments, Teasdale et al. (1995) determined that producing these intrusive thoughts involves the central executive. They had research participants practice either a spatial task (keeping a light beam in a pencil-like instrument focused on a revolving circle; this is called a *pursuit rotor task*) or a memory task (keeping a specific digit in mind when the specific digit changed every 4 seconds). Next all participants performed both tasks and were again interrupted at various points and asked to report their thoughts. The researchers found that whichever task had been practiced produced far less interference with SITs than did the unpracticed task. In other words, when you or I perform a novel and challenging task, we are far less likely to experience intrusive, unrelated thoughts (for example, about the fight we just had with our partner, or about a dream vacation we hope to take someday) than if we are working at a task at which we are well practiced.

Note the fit of this explanation with the topics we discussed in Chapter 4. Presumably, tasks that have been practiced require less attention, or, in Baddeley's terminology, require fewer resources from the central executive of working memory. That capacity is thus available for the mind to do other things—for instance, to think about unrelated things. Unpracticed, demanding tasks, in contrast, "soak up" more central executive resources, leaving them unavailable to produce unrelated intrusive thoughts.

Teasdale et al. (1995) pointed out a practical implication of their research. Suppose you want to stop worrying about an issue. Tasks in which you simply repeat memorized phrases or chant the same word or phrase over and over again are not likely to be very effective, because they don't require enough of your central executive resources to block out the worrisome thoughts. Instead, Teasdale et al. proposed that you engage in a task in which you need to "make continuous demands on the control and coordinating resources of the central executive" (p. 558). One suggestion is to try to generate a word or phrase at random intervals, which requires you to continuously monitor your performance and coordinate your current response with your past responses.

Baddeley (1992) regarded his proposal about working memory as an evolution of the STM idea, rather than a competing proposal. Moving away from a view of STM as a passive, temporary, limited-capacity storehouse, Baddeley and others are now investigating the active role played by the processing system that is operating on current information and are separating this function from the temporary storage of information. Working memory is thought to be involved in translating visual information into an acoustic code, forming chunks, rehearsing to keep attention focused on material to remember (as in the phone number example, earlier), and sometimes elaborating incoming information by calling up relevant knowledge from LTM. Thus the term *working memory* conveys more than a temporary storehouse; rather, it connotes a place where the person exerts active mental effort to attend to, and often to transform, the material.

Indeed, Baddeley believes that WM supports conscious functioning, and that it

> has evolved as a means of allowing the organism to consider simultaneously a range of sources of information about the world, and [to use] these processes to set up mental models that facilitate the prediction of events and the planning of action. Consider, for example, the task of a hunter-gatherer who recollects that at this time of year a tree bears fruit near a waterfall in potentially hostile territory. In order to reach the tree safely, he may need to use remembered spatial cues, together with the sound of the waterfall and the shape of the tree, while listening and looking for signs of potential enemies. A dynamic image that is capable of representing these varied sensory features simultaneously is likely to provide a planning aid of considerable evolutionary value. (Baddeley & Andrade, 2000, p. 128)

## ■ EXECUTIVE FUNCTIONING

Recall from Chapter 4 the finding that in a dichotic listening tasks, people with higher working-memory (WM) capacity are *less* likely to detect their names in the unshadowed message (Conway, Cowan, & Bunting, 2001). A variety of other studies, reviewed by Engle and colleagues (Barrett, Tugade, & Engle, 2004; Engle, 2002; Unsworth & Engle, 2005), show other individual differences as a function of WM capacity on very different tasks.

One task studied by Kane, Bleckley, Conway, and Engle (2001) is called an "antisaccade" task. Research participants sit before a visual display and are asked to fixate their eyes in the middle of the screen. Then a stimulus (a letter to identify) is presented briefly on one side or the other of the screen, forcing the participant to attend to that stimulus in order to make the proper response as quickly as possible. Now, just before that stimulus is presented, the experimenters flash a cue of some sort. Sometimes this cue is presented on the same side of the screen the stimulus will appear on. The authors call this the "prosaccade" task, because the cue presumably causes the participant to automatically look at (by moving his eyes sideways with a saccade) the correct side of the visual display. In this condition, no differences appeared in reaction time to identify the target letter for participants with either very high WM capacity or very low WM capacity.

However, large differences arose in performance between high-WM and low-WM capacity in the *antisaccade* task, in which a cue appeared on the opposite side of the screen from where the target would appear. To perform optimally at this task, the research participant had to resist the temptation to have his attention drawn to the misleading cue. Now, this is a tough temptation, and everyone shows slower reaction time in this condition, relative to the prosaccade condition. However, the performance of low-WM-capacity participants was hurt more than that of high-WM-capacity participants.

In another study, Kane and Engle (2000) showed that low-WM-capacity individuals were more susceptible than high-WM-capacity individuals to the effects of proactive interference. However, when participants were given a second task, high-WM-capacity participants showed the same level of proactive interference as did low-WM-capacity participants. Engle (2002) believes that under normal conditions, high-WM individuals control their attention to resist the effects of proactive interference. In interpreting this set of results,

> my sense is that WM capacity is not about individual difference in how many items can be stored per se but about differences in the ability to control attention to maintain information in an active, quickly retrievable state. . . . WM capacity is not directly about memory—it is about using attention to maintain or suppress information . . . greater WM capacity also means greater ability to use attention to avoid distraction. (Engle, 2002, p. 20)

Other researchers have also found correlations between WM capacity and the ability to reason from premises, a topic we will consider in Chapter 12 (Markovits, Doyon, & Simoneau, 2002), and the ability to overcome the effects of postevent misleading information in an eyewitness memory task, a topic discussed in Chapter 7 (Jaschinksi & Wentura, 2002). Indeed, some authors link WM capacity to general fluid intelligence, a topic we'll explore in more depth in Chapter 15 (Suess, Oberauere, Wittman, Wilhelm, & Schulze, 2002).

We have seen a lot of growth and evolution of the concept of STM into WM. It makes sense to pause here and consider the key differences between the two concepts. Cowan (1995), Engle (2002), and Kail and Hall (2001), among others, have presented strong empirical evidence and theoretical arguments to suggest that STM and WM are distinct. STM can be thought of as information that is actively being processed, perhaps even information from long-term memory that is currently activated. WM included these active memory traces *as well as* the attentional processes used to maintain that activation and to keep the person focused on the primary cognitive task at hand.

In terms of the diagram in Figure 5-1, we can describe the development of the WM concept as the articulation of different STM components. Instead of regarding STM as a single entity, we are conceptualizing it in a new way and giving it a new name to indicate that it includes several components and is involved in a variety of forms of cognitive processing.

## ■ NEUROLOGICAL STUDIES OF MEMORY PROCESSES

Memory processes ultimately are instantiated in the brain, of course, and we will pause now to consider some relevant background and findings from the study of neuropsychology. Previous discussion of "stores" or "components" of memory can make it seem as if memory were located in one place in the brain—a sort of neural "filing cabinet" that holds onto memory traces of information being stored.

Actually, however, the picture emerging from neuropsychological studies is quite different and much more complicated. Memories don't all seem to be "stored" in one place. Desimone (1992) noted that in humans and animals, lesions of the cerebellum, a motor control structure, impair the acquisition of classically conditioned motor responses; lesions or disease of portions of the striatum, which normally functions in sensorimotor integration, impair stimulus–response learning of habits; lesions of the inferior temporal cortex, an area important for visual discrimination, impair visual recognition and associative memory; and lesions of the superior temporal cortex, an area important for auditory discrimination, impair auditory recognition memory.

> The medial temporal lobe is a major site of multimodal convergence, and it contains neurons that are sensitive to the configuration of many environmental stimuli as well as to the behavioral context in which events occur; thus it is not surprising that this region is critical for forming long-term explicit memories. (p. 245)

Much of the interest in "localizing" memory in the brain dates back to a famous case study. In 1953, William Beecher Stover, a neurosurgeon, performed surgery on H.M., a 27-year-old epileptic patient. Before the operation, H.M. was of normal intelligence. Stover removed many structures on the inner sector of the temporal lobes of both sides of H.M.'s brain, including most of the hippocampus, the amygdala, and some adjacent areas (see Figures 5-9 and 5-10). This noticeably reduced H.M.'s seizures, and H.M.'s postoperative IQ actually rose about 10 points (Schacter, 1996).

Unfortunately, however, H.M. suffered another decrement: He lost his ability to transfer new episodic memories into long-term memory, and thus became one of the most famous neuropsychological case studies in the literature. H.M. could remember semantic information (see Chapter 7 for a fuller discussion), and events that he had experienced several years before the operation.

**FIGURE 5-9** ■ *Subcortical structures of the brain.*

**SOURCE:** Goldstein (1994, p. 89).

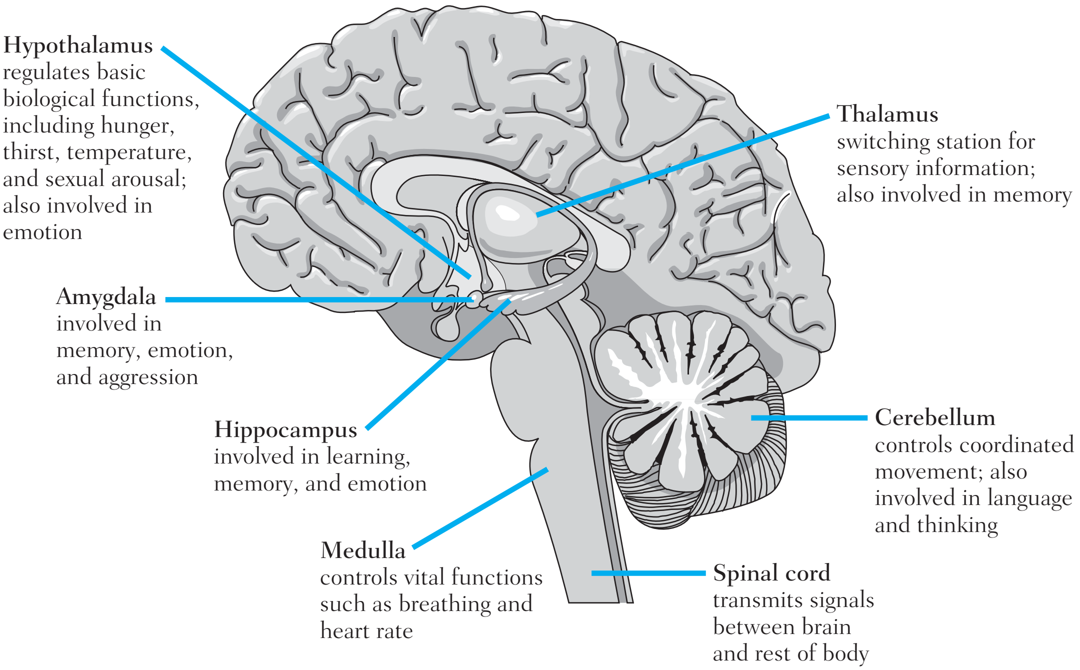
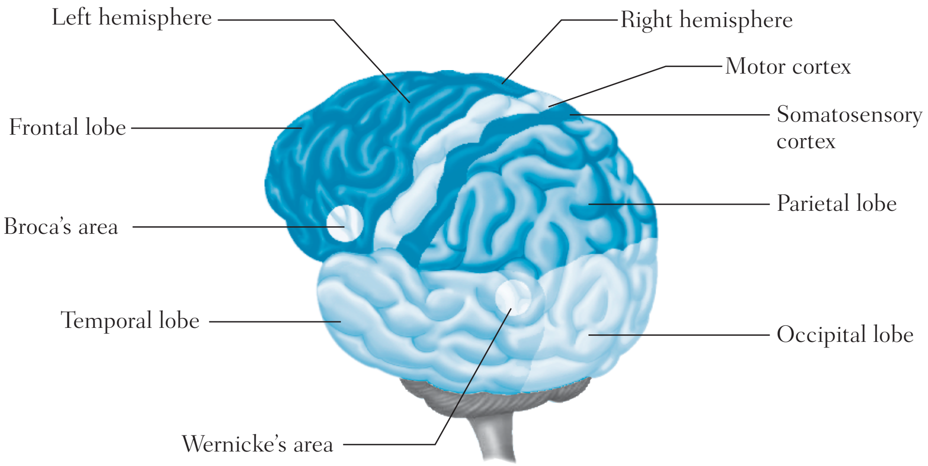

**Hypothalamus**
regulates basic biological functions, including hunger, thirst, temperature, and sexual arousal; also involved in emotion
**Thalamus**
switching station for sensory information; also involved in memory
**Amygdala**
involved in memory, emotion, and aggression
**Hippocampus**
involved in learning, memory, and emotion
**Cerebellum**
controls coordinated movement; also involved in language and thinking
**Medulla**
controls vital functions such as breathing and heart rate
**Spinal cord**
transmits signals between brain and rest of body

**FIGURE 5-10** ■ *The cerebral cortex. The cerebral cortex is divided into two hemispheres, left and right, and each hemisphere can be divided further into four parts, or lobes.*

**SOURCE:** Nairne (1997, p. 89).



However, H.M. could no longer form new memories of new events. He could remember a series of seven or so digits, as long as he was not distracted, but if he turned his attention to a new task, he could not seem to store that (or much other) information. In addition to this **anterograde amnesia** (amnesia for new events), H.M. had **retrograde amnesia** (amnesia for old events) for the period of several years just before his operation.

H.M.'s case, widely publicized by psychologist Brenda Milner in the hope of preventing similar surgeries this extensive, suggested strongly that the structures removed from his brain, especially the rhinal cortex and underlying structures, played a major role in forming new memories. Other researchers reported other case studies and other animal studies that seemed to provide corroborating evidence.

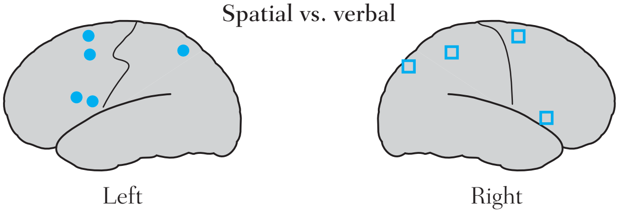
H.M.'s case was also taken as evidence to support the distinction between long-term (perhaps very long-term) memories, which seemed accessible, at least for events several years before the operation, and short-term memories, which seemed unstorable. As we will see in Chapter 7, this statement seems to work only for certain kinds of memories, so the picture is a bit more complicated.

Findings from other brain-damaged people have implicated areas in the frontal lobe as having much to do with WM, perhaps because frontal-lobe damage is often reported to disrupt attention, planning, and problem solving (that is, the central executive in Baddeley's model; see Gathercole, 1994). Shimura (1995) suggested that these problems may arise not because attention and planning are located in the frontal lobe but rather because areas of the frontal lobe inhibit activity in the posterior part of the brain. People with frontal-lobe damage seem more distractible and less able to ignore irrelevant stimuli.

PET scan studies also give us more information about the neural underpinnings of memory. Recall that for PET studies, patients are injected with a radioactive compound, then asked to lie still with their head in a doughnut-shaped scanner (Posner & Raichle, 1994). This scanner measures blood flow in different brain regions. The idea is that when a particular area of the brain is being used in a cognitive activity, more blood flows to that area. Smith and Jonides (1997) reported that PET study results confirm many aspects of Baddeley's model of working memory—in particular, different patterns of activation for verbal WM (localized primarily in the left frontal and left parietal lobes; see Figure 5-10) versus spatial WM (localized primarily in the right parietal, temporal, and frontal lobes; see Figure 5-11). Nyberg and Cabeza (2000) reviewed brain-imaging studies of memory conducted in many different laboratories and reported similar findings.

**FIGURE 5-11** ■ *Schematic representation of PET activations in left and right hemispheres for the one-dimensional tasks, with control activations subtracted. The filled circles designate activations in the verbal task, and the squares indicate activations in the spatial task. Some activated areas are not shown in the schematics because they were in a midline structure (the anterior angulate, which was activated in both the verbal and object tasks) or in subcortical regions (the left-hemisphere thalamus and right-hemisphere cerebellum, activated in the verbal task) or beneath the lateral surface of the cortex (left-hemisphere insular cortex, activated in the verbal task).*

**SOURCE:** Smith and Jonides (1997, p. 11).



Other researchers have conducted fMRI studies on what brain regions are activated when information is remembered. Wagner et al. (1998), for example, reported that verbal material that was encoded and remembered produced more activation in certain regions of the frontal and temporal lobes. A similar fMRI study of people learning to remember photographs also indicated greater activity in parts of the left prefrontal and medial temporal lobes (Brewer, Zhao, Desmond, Glover, & Gabrieli, 1998).

How does the activity of different brain regions change as memories are formed? We are far from reaching a complete answer to this question. However, some preliminary answers are emerging. Neil Carlson (1994) described some basic physiological mechanisms for learning new information. One basic mechanism is the *Hebb rule,* named after the man who posited it, Canadian psychologist Donald Hebb. The Hebb rule states that if a synapse between two neurons is repeatedly activated *at about the same time* the postsynaptic neuron fires, the structure or chemistry of the synapse changes. A more general, and more complex, mechanism is called **long-term potentiation.** In this process, neural circuits in the hippocampus that are subjected to repeated and intense electrical stimulation develop hippocampal cells that become more sensitive to stimuli. This effect of enhanced response can last for weeks or even longer, suggesting to many that this could be a mechanism for long-term learning and retention (Baddeley, 1993b). As you might suspect, disrupting the process of long-term potentiation (say, through different drugs) also disrupts learning and remembering.

Despite the intriguing results from neuropsychological studies, we are far from having a complete picture of how the brain instantiates all, or even many, memory phenomena. It is not clear which aspects of memory are localized in one place in the brain and which are distributed across different cortical regions. It is not clear what kinds of basic neural processes are involved in any one particular complex cognitive activity. Tulving (1995) made the point quite explicitly:

> Memory is a biological abstraction. There is no place in the brain that one could point at and say, Here is memory. There is no single activity, or class of activities, of the organism that could be identified with the concept that the term denotes. There is no known molecular change that corresponds to memory, no behavioral response of a living organism that is memory. Yet the term *memory* encompasses all these changes and activities. (p. 751)

Tulving noted further that neuroscientists today reject the idea of studying memory as though it were a single process. Instead, they are likely to look for neurological underpinnings at a more precise level—at such processes as encoding or retrieval.

## SUMMARY

1. Memory is a very basic cognitive process used in almost every cognitive activity. It involves encoding information, storing it, and later retrieving it from that storage. Cognitive psychologists consider memory an active, constructive process. This means the information does not "sit still" in a storehouse, waiting to be retrieved, but instead is elaborated and sometimes distorted or constructed.
2. One approach to the study of memory, called the *modal approach,* divides memory into different types: *sensory memory,* which holds information in specific modalities

for fractions of a second up to several seconds (depending on the modality); *STM,* which holds a limited amount of information for brief periods of seconds or minutes; and *LTM,* which holds onto memories for longer periods of time.

3. The number of unrelated pieces of information that can be held in the short term (without rehearsal or recoding) seems to be seven, plus or minus two. This limit can be overcome through techniques such as *chunking,* which requires some knowledge about the pieces of information and how they relate.
4. There is controversy in the explanations proposed for why we forget information. The question is whether information in a memory store ever decays or "disintegrates" or whether all supposedly "forgotten" information is actually buried information displaced by interference from other information. Although these two possibilities are quite distinct, as a practical matter it is very difficult to design critical experiments that would rule out one of them. Perhaps both kinds of processes play some role in forgetting.
5. Saul Sternberg's work suggests that retrieval from STM is serial and exhaustive. Later work suggests that this may depend on the nature of the stimuli presented.
6. A newer conception of STM, proposed by Alan Baddeley, is called *working memory (WM).* Working memory is thought to consist of a *central executive,* concerned with coordinating and controlling incoming information; a *phonological loop,* acting as an inner "ear"; and a *visuospatial sketch pad,* used as an inner "eye." Recent work suggests that WM capacity is a powerful variable, relating to the ability to resist distraction and distortion, to reason with abstract or concrete premises, and to maintain control of attention more generally.
7. Neuropsychological studies of memory provide a glimpse at some very exciting "cutting-edge" research. Investigators are examining the role of particular brain structures, such as the hippocampus and medial temporal cortex, in memory formation, as well as attempting to localize the brain regions involved in encoding and retrieval.

## REVIEW QUESTIONS

1. Review the evidence that has led some psychologists to posit the existence of different memory stores (such as sensory memory, short-term memory, long-term memory).
2. Discuss the importance of research on icons and echoes for understanding how people process incoming information. Consider issues of both experimental control and ecological validity.
3. Psychologists have posited two distinct mechanisms for forgetting: decay and interference. Describe each, briefly review the experimental evidence supporting each, and state the problem in distinguishing between them.

4. Describe the methods used in S. Sternberg's memory-scanning experiment. What do the results tell us about retrieval of information from STM?
5. How does Baddeley's conception of working memory differ from traditional descriptions of STM?
6. Explain why WM capacity, but not STM capacity, would relate to performance on so many other cognitive tasks (such as proactive interference, dichotic listening, and reasoning).
7. Describe two ways in which our knowledge of findings from research on working memory can help us design effective real-world strategies for coping with everyday tasks and problems.
8. Summarize the findings of neuropsychological research on localizing memory in the brain.

## KEY TERMS

anterograde amnesia
capacity
central executive (of WM)
chunking
coding
decay
echo
encoding
exhaustive search
forgetting
icon
interference
long-term memory (LTM)
long-term potentiation
memory trace
modal model of memory
parallel search
phonological loop (of WM)
primacy effect
proactive interference
recency effect
rehearsal
retention duration
retrieval
retrograde amnesia
self-terminating search
sensory memory
serial position effect
serial search
short-term memory (STM)
storage
visuospatial sketch pad (of WM)
working memory (WM)

## CogLab DEMONSTRATIONS

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

CogLab, a web-based set of demonstrations in cognitive psychology, provides several demonstrations of memorial phenomena discussed in this chapter. Here are four I particularly want to call to your attention: The **Partial Report** demonstration will provide you with experience with Sperling's icon. The **Brown–Peterson** demonstration presents an adapted version of the recall of a trigram task. The **Sternberg Search** demonstration allows you to participate in a short-term memory search experiment, and the **Serial Position** demonstration gives you experience with serial position curves.

## WEB RESOURCES

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

## CHAPTER

## 6

# Retrieving Memories From Long-Term Storage

**The Traditional View of Long-Term Memory**
- Capacity
- Coding
- Retention Duration
- Forgetting
- Retrieval of Information

**The Levels-of-Processing View**

**The Reconstructive Nature of Memory**
- Autobiographical Memory
- Flashbulb Memories
- Eyewitness Memory
- The Recovered/False Memory Debate

**Amnesia**
- Anterograde Amnesia
- Retrograde Amnesia

In the last chapter, we focused on the formation of new memories and on memories held for brief periods of time—fractions of a second, a few seconds, or a minute. In this chapter, we will focus on memories held for longer periods—several minutes, hours, weeks, years, and even decades. The kind of memory we'll be talking about corresponds better than STM does to the layperson's definition of a memory: information retrieved after some long period of storage.

We will begin by looking at the traditional view of long-term memory, the modal model of memory. Recall that this model of memory emphasizes the different memory stores: sensory, short term, and long term. Next we'll turn our attention to other models of memory that focus less on the type of memory store and more on the way information is processed, both at the time of encoding and at the time of retrieval. We'll look at how various cues become associated, either intentionally or unintentionally, with the information to be remembered, and then at how these cues can be used to maximize the chances of retrieving information.

Our third major topic will be a look at the malleability of memory. In this section, we'll review research on memory for events, and how those memories can be distorted without a person's awareness. Finally, we will look in greater detail at the topic of amnesia, reviewing the different types of amnesia. We'll examine what the clinical data so far tell us about the laboratory-based theories of memory organization.

## ■ THE TRADITIONAL VIEW OF LONG-TERM MEMORY

In the modal model, long-term memory (LTM) is thought to differ from short-term memory (STM) in many ways. LTM is described as a place for storing large amounts of information for indefinite periods of time. Note the contrast here with the modal description of STM as holding a very limited amount of information (seven, plus or minus two, pieces of unrelated information) for a very short period of time (seconds or at most a few minutes). In other words, LTM is commonly thought to be a sort of mental "treasure chest" or "scrapbook": The material you have cognitively collected in your lifetime is stored there in some form. In this section, we will examine the capacity, coding, storage, and retrieval of information from long-term storage, as well as review evidence bearing on forgotten material.

### Capacity

What is the capacity of LTM? The question cannot be answered with a single number. Think about information you have stored in your LTM. It would have to include your memory of all the word meanings you know (probably between 50,000 and 100,000), all the arithmetic facts, and all the historical, geographic, political, and other kinds of information you've learned. You also probably stored in LTM at one time or another the names and faces of all sorts of people: family members, significant teachers, neighbors, friends, enemies, and others. You also surely have stored various pieces of other information about each of them: physical attributes, birthdays, favorite color or musical group, and so on. All your information about various ways of doing familiar things—getting a transcript from the registrar's office; checking out a book from the library; asking for, accepting, or turning down a date; finding a phone number; addressing a letter—must also be in LTM. Indeed, a complete list of all information you have at one time or another put into long-term storage would be very long. This intuition has led psychologists to estimate that the capacity of LTM is virtually unlimited.

Thomas Landauer (1986) has tried to provide a more quantitative answer to this question. He begins with two previous estimates. The first is that the size of human memory is equal to the number of synapses in the cerebral cortex of the brain. As you may remember from your introductory psychology course, a synapse is the gap between two neurons, basic cells of the body, across which neurotransmitters pass chemical messages. The cerebral cortex has $10^{13}$ synapses, so some believe that human memory can hold $10^{13}$ distinct bits of information.

Another estimate is $10^{20}$ bits of information, the estimated number of neural impulses, or electrical messages, transmitted within the brain during a person's lifetime. Landauer argued that both these estimates are probably too high: Not every neural impulse or synaptic connection results in a memory. Through various different analyses, in which he tried to estimate the rate at which new information is learned and the rate at which information is forgotten or lost, he came to an estimate of about 1 billion bits of information for an adult at midlife (say, about age 35).

Whatever the actual number of bits of information stored in LTM, not all that information is retrievable at any given moment. Indeed, there are many everyday examples of failures to retrieve information. You meet someone you know you know but can't place, or you think of a word but can't name it. The information probably is in your long-term storage somewhere, but you somehow can't access it. We'll return to the issues of retrieval and forgetting later.

## Coding

Many studies of recall from LTM report a common finding: Errors made while recalling information from LTM are likely to be semantic confusions. That is, words or phrases that mean things similar to the words or phrases actually presented are likely to be "recalled" in error, if errors are made. Baddeley (1966a) demonstrated this phenomenon experimentally. He presented participants with lists of words that sounded similar (such as *mad, map, man*) or that were matched to the first list but did not sound alike (such as *pen, day, rig*). Others also saw a list of words with similar meanings (such as *huge, big, great;* such words are called "semantically similar") and another list of control words that were matched to the third list but did not share meaning (such as *foul, old, deep*). Recall was tested after a 20-minute interval, during which participants worked on another task, to prevent rehearsal and to ensure the material would be drawn from long-term rather than short-term storage. The results showed that acoustic similarity produced little effect on performance but that the list of semantically similar words was harder to learn. Baddeley (1976), reviewing this and other work, concluded that the following generalization, although not absolute, is roughly true: Acoustic similarity affects STM; semantic similarity affects LTM.

## Retention Duration

How long can information be stored in LTM? Although most laboratory experiments test recall after several hours or days, evidence is abundant that at least some information can last for decades or even a lifetime. Harry Bahrick (1983, 1984) has studied people's memory for material learned to varying degrees at varying times, including memory for the faces of college classmates 20 or 30 or even 50 years after graduation.

In one study, Bahrick (1984) tested 733 adults who had taken or were taking a high school or college course in Spanish. The participants who were not currently enrolled in a Spanish course had not studied Spanish for periods ranging from 1 to 50 years. They also varied in their original degree of learning of Spanish. Bahrick plotted "forgetting curves" for different aspects of knowledge of Spanish—for example, grammar recall and idiom recognition. Although forgetting differed slightly as a function of the measure, the pattern of results was remarkably consistent. For the first 3 to 6 years after completing Spanish study, participants' recall declined. But for the next three decades or so, the forgetting curve was flat, suggesting no further loss of information. Retention showed a final decline after about 30 to 35 years.

Bahrick (1984) interpreted the findings as follows:

> Large portions of the originally acquired information remain accessible for over 50 years in spite of the fact the information is not used or rehearsed. This portion of the information in a "permastore state" is a function of the level of original training, the grades received in Spanish courses, and the method of testing (recall vs. recognition), but it appears to be unaffected by ordinary conditions of interference. (p. 1)

So you thought that after the final exam you'd forget everything about cognitive psychology? If your professor contacts you in 20 years or so, you might surprise both of you: You'll probably remember at least some of the course material!

Another study of Bahrick's (1983) examined people's recall of the spatial layout of a city over a period of time ranging from 1 to 50 years. Bahrick's research participants were 851 current students and alumni of Ohio Wesleyan University, where he was on the faculty. Bahrick asked his participants to describe the campus and the surrounding city of Delaware, Ohio. Specifically, he asked participants:

1. To list all the street names in Delaware that they could recall and to categorize each as running north–south or east–west
2. To recall names of buildings and landmarks in the city and on the campus
3. Using a map provided, to write down the names of all the streets, buildings, and landmarks indicated on the map

4. Given a list of streets or buildings and landmarks, to cross out ones they did not recognize and to categorize each street as running north–south or east–west or to order the landmarks/buildings recognized on the two compass directions
5. Given the map and the lists, to match the street names to the streets and the buildings/landmarks to the indicated squares

Bahrick also asked participants how long they had lived in Delaware (excluding alumni who had lived in the town for more than two years before or after their undergraduate years), the frequency of their visits back to Delaware (for the alumni), and the frequency with which they had driven a car around Delaware and/or used maps. Bahrick used these data to adjust for the fact that some participants had more and/or different kinds of experience with the city than others.

Using the data from the current students, Bahrick (1983) plotted information acquisition as a function of time spent in Delaware. His results show learning of street names occurred at a steady rate over 36 months of residence. In contrast, the learning of building and landmark names showed a steeper curve, with most learning occurring during the first year. Bahrick speculated that the difference in learning rates stems from the facts that campus locations are much more important to learn for students than are the names of streets and that students spend much more time walking around a small area of the city and campus than they spend driving around the city streets.

Bahrick (1983) assessed retention of information by surveying alumni who had graduated from 1 to 46 years previously. These findings were in some ways the inverse of the learning data. Street names (which had been learned slowly and steadily) were forgotten quickly (see Figure 6-1): Most information about street names was lost after 10 years. Names of landmarks and buildings (see Figure 6-2) faded more slowly; 46 years after graduation, alumni retained about 40% of the information that current graduating seniors had (the test included only landmarks and buildings that had existed for 50 years).

## Forgetting

If information can last indefinitely in LTM, why does so much of it seem unavailable, even a week later? There are several familiar examples: “knowing” you know the answer to an exam question but being unable to quite remember it; meeting someone on the street who is extremely familiar but you don’t know from where. What has happened to your memory in these instances? Has it been erased somehow?

**FIGURE 6-1** ■ *Adjusted retention curves of street names.*

**SOURCE:** Bahrick (1983, p. 138).

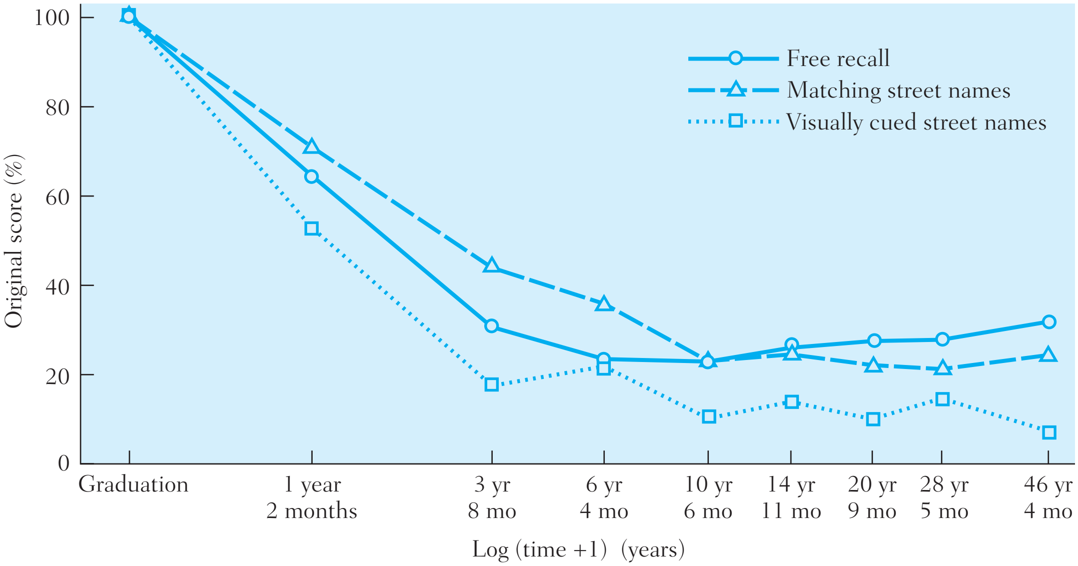
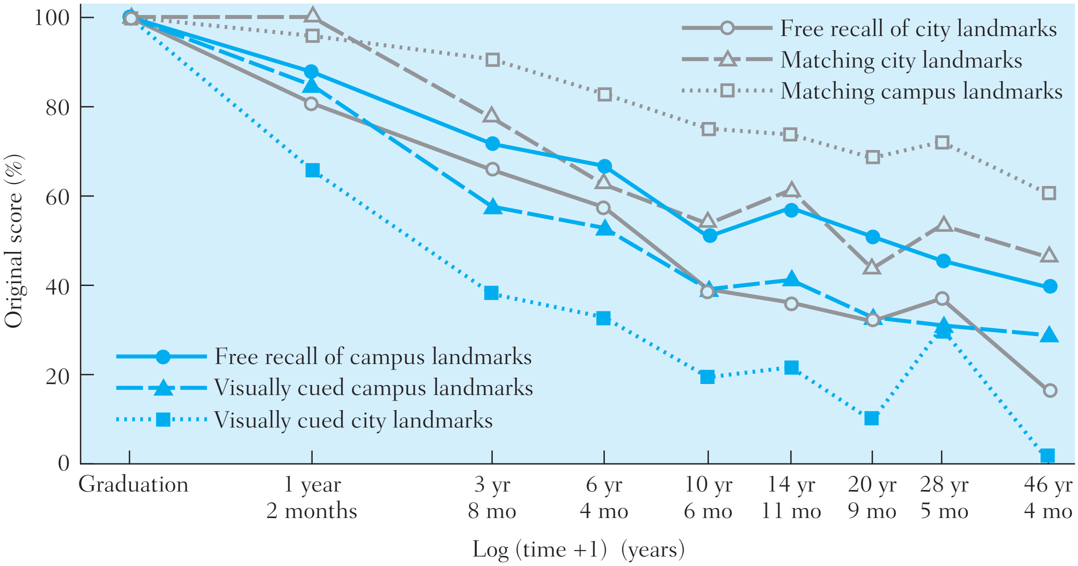


**FIGURE 6-2** ■ *Adjusted retention curves of landmarks.*

**SOURCE:** Bahrick (1983, p. 153).



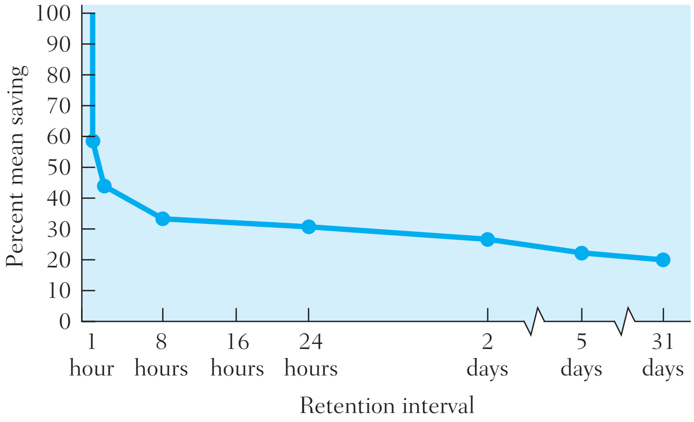
Forgetting or even “misremembering” is a topic that dates back to the early days of experimental psychology. Hermann Ebbinghaus, a Prussian psychologist, pioneered the empirical study of memory under controlled conditions (Hoffman, Bamberg, Bringmann, & Klein, 1987). His master work (Ebbinghaus, 1885/1913) reported on 19 of his studies using himself as a subject.

Ebbinghaus created stimuli he thought were carefully controlled and free from any contamination from prior learning; he called them *nonsense syllables* (such as *rur, hal*, and *beis*). He carefully and precisely presented, at a controlled rate, hundreds of lists of these syllables to a single and dedicated subject: himself. Day after day, Ebbinghaus memorized, tested himself, recorded the results, and prepared new stimuli. Altogether, he spent about 830 hours memorizing 85,000 syllables in 6,600 lists (Hoffman et al., 1987). The primary questions he asked had to do with the number of repetitions needed for perfect recall, the nature of forgetting, the effects of fatigue on learning, and the effects of widely spaced versus closely spaced practice.

One of Ebbinghaus’s many findings is presented in Figure 6-3. Depicting a “forgetting curve,” the graph plots the amount of time it took him to relearn a list of nonsense syllables after initial learning followed by a retention interval of varying amounts of time (the retention interval is plotted on the *x* axis). Ebbinghaus assumed that the more forgetting, the more effort it would take to relearn a list; conversely, the less forgetting, the less effort to relearn. The curve suggests that forgetting is not a simple linear function of time. Instead, forgetting is rapid at first and then levels off. Notice how well this laboratory finding anticipates the real-world memory studies of Bahrick, reported earlier.

**FIGURE 6-3** ■ *Ebbinghaus’s (1885/1913) forgetting curve.*

**SOURCE:** Ebbinghaus (1885/1913, p. 76).



As with STM, many psychologists believe that interference, not decay, accounts for "forgetting" from LTM (McGeoch, 1932). They believe material that can't be retrieved successfully from LTM is there but "buried" or in some other way unavailable. (You may want to review Chapter 5 for a discussion of decay versus interference accounts of forgetting.)

Much of the literature on interference has used a task called **paired associates learning.** Participants hear lists of pairs of words such as *flag–spoon* and *drawer–switch*. After one or more presentations of a list, the experimenter then presents participants with the first word in each pair—for example, *flag*—and the participant is asked to recall the word originally paired with it, such as *spoon*.

Researchers have used this task to study interference in two ways (see Table 6-1). The first is through *proactive interference (PI),* a phenomenon described in Chapter 5. The term *PI* refers to the fact that previous learning can make retention of subsequent learning more difficult. Thus if a group of participants learns a list of paired associates ("List A–B" in the table) and then learns a second list with the same set of first terms but new second ones ("List A–C" in the table), recalling information from the second list is harder.

**Table 6-1** Experimental Paradigms for Assessing Proactive and Retroactive Interference

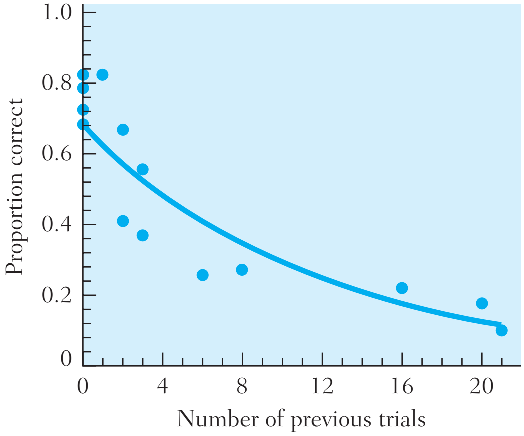
| *Phase* | *Experimental Group* | *Control Group* |
|---|---|---|
| ***Proactive Interference*** | | |
| I | Learn List A–B | (Unrelated activity) |
| II | Learn List A–C | Learn List A–C |
| Test | List A–C | List A–C |
| ***Retroactive Interference*** | | |
| I | Learn List A–B | Learn List A–B |
| II | Learn List A–C | (Unrelated activity) |
| Test | List A–B | List A–B |

A more familiar example of proactive interference might come from foreign language vocabulary learning. Imagine you are taking beginning courses in French and in German at the same time and for some perverse reason you decide to study their vocabularies sequentially. You first learn a list of French words by pairing them with their English alternatives—for example, *dog–chien*. Next, you learn the German equivalents for the English words, again by pairing—for example, *dog–Hund*. If we compare how well you perform on a test of German vocabulary to the performance of your roommate (who is not studying French), we'll generally find, all other things being equal, that your recall is not as good. We call the kind of interference you experience *proactive* to indicate that earlier material is interfering with subsequent material.

Underwood (1957) demonstrated the effects of proactive interference using the data from 14 studies (see Figure 6-4). These data show that the more previous experience (that is, number of experimental trials) a person has with a particular task, the worse that person's performance is on the current trial.

**FIGURE 6-4** ■ *Proportion correct plotted as a function of the number of previous trials. Data were collected from 14 different studies.*

**SOURCE:** Neath (1998, p. 141), adapted from Underwood (1957).



The other kind of interference is called **retroactive interference.** Imagine you and another friend both study a list of English words and their French equivalents. Your friend now works on a physics problem set while you work on a list of the same English words with their German equivalents. The next day, you and your friend take a quiz in French class. All other things being equal, your recall of French will be worse than your friend's, because of retroactive (or backward) interference. Presumably, your recall of French is contaminated by intrusions of your recall of German.

Some researchers have argued that interference plays a role in most, if not all, forgetting of material from the long-term storage system (Barnes & Underwood, 1959; Briggs, 1954; Postman & Stark, 1969). Of course, it is impossible to rule out the idea that decay occurs, because it is impossible to design a task in which interference cannot occur.

How exactly does interference work? Anderson and Neely (1996) presented several possibilities. They started with the assumption diagrammed in

Figure 6-5(A): that a **retrieval cue** points to, and leads to the recovery of, a target memory. However, when that retrieval cue becomes associated to other targets, during retrieval the second target "competes" with the first. Anderson and Neely offered the following example:

> Consider, for example, the deceptively simple task of recalling where you parked your car at a local shopping center. If you have never before been to that shopping center, recalling your car's location may be fairly easy. If you park there frequently, however, you may find yourself reunited with the spot where you parked yesterday or, if you are like the present authors, standing befuddled at the lot's edge. Further, if asked where you parked on previous visits, you would almost certainly fail to recall the locations, as though your intervening parking experiences had overwritten those aspects of your past. (p. 237)

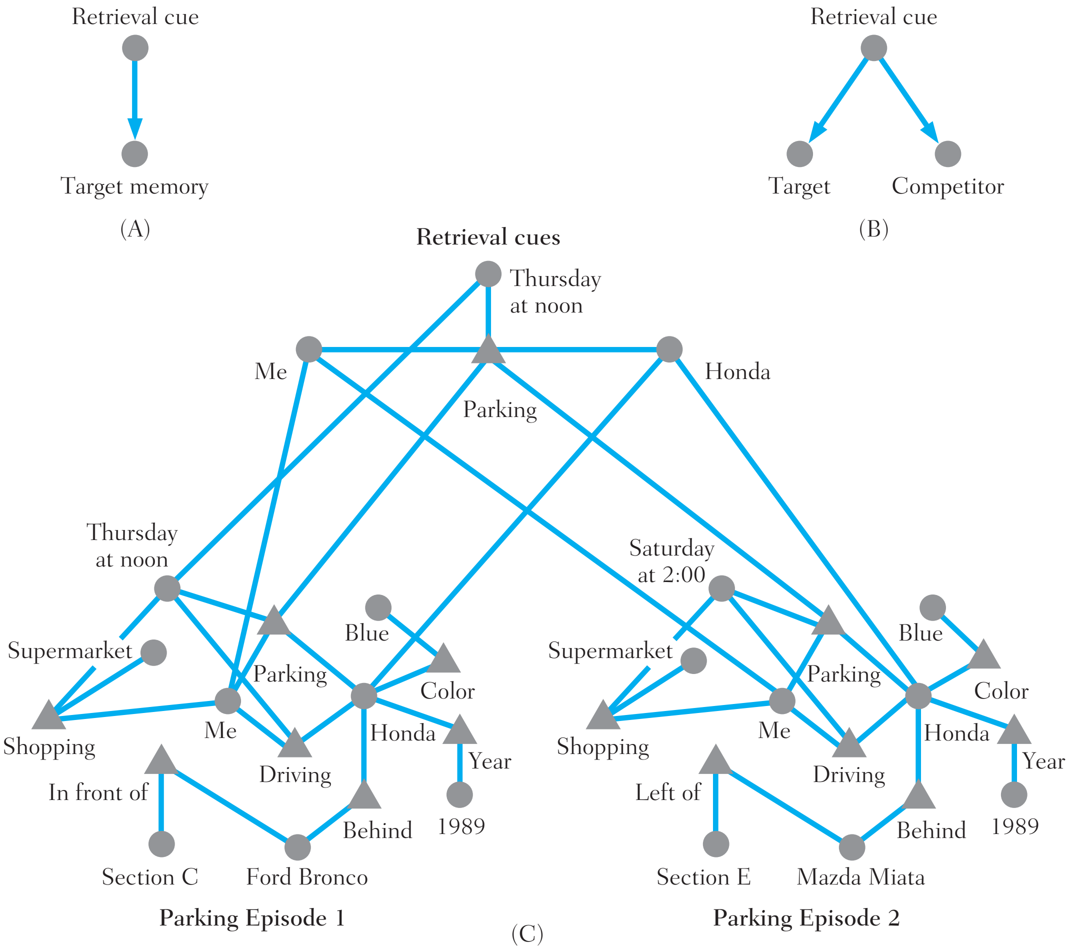
Put in terms of Figure 6-5(B), the more times you park in a particular parking lot, the more "targets" (actual parking spots) get associated with a retrieval cue (such as the question you ask yourself as you leave the store, "Now where did I park?"). The more possible targets associated with the cue, the less the chances of finding any particular one of them. Complicating matters even further, a given retrieval cue can become associated with different targets (or other cues), leading to even more complexity, as diagrammed in Figure 6-5(C), and making it that much harder to traverse a path from the cue to the correct target.

To account for some of these results, psychologist John Anderson (1974; Anderson & Reder, 1999) described a phenomenon known as the **fan effect.** Anderson's idea is that as research participants study more facts about a particular concept, the time they need to retrieve a particular fact about that concept increases. So, for example, if you study lots of facts about forgetting, your ability to recall any individual fact about it (for example, that many psychologists think it is caused by interference) is slowed.

Anderson and Neely (1996) speculated that forgetting may not be so much a shortcoming of memory as a side effect of our ability to direct memory. In particular, they wonder whether sometimes it is beneficial to be able to forget voluntarily. Example: You are working for the summer break as a short-order cook. Servers spend their time shouting orders at you: "Egg salad on wheat, lettuce, no mayo!" It behooves you both to maintain this information in immediate memory as you construct the sandwich *and* to clear this information when you are done so it does not interfere with newer incoming orders. Laboratory work that Anderson and Neely reviewed suggests that when people lose information through "directed" (voluntary or intentional) forgetting, they experience much less proactive interference. Forgetting, then, can be a useful thing to do!

**FIGURE 6-5** ■ *Illustration of the notion of competition among items sharing the same retrieval cue. (A) A retrieval cue that is associated to only one target item in memory. (B) The basic situation of interference, in which a retrieval cue becomes associated to one or more additional competitors that impede recall of the target, given presentation of the shared retrieval cue. (C) How the basic situation of interference illustrated in (B) may be applied to understand a more complex example of interference in which two episodes of having parked at the supermarket interfere because they share the retrieval cues "Me," "Honda," and "Parking" at the time of retrieval. Circles and triangles in the representations of Episodes 1 and 2 in (C) depict concepts and relations, respectively.*

**SOURCE:** Anderson and Neely (1996, p. 240).


Retrieval cue
Target memory
(A)
Retrieval cue
Target
Competitor
(B)
Retrieval cues
Thursday at noon
Me
Parking
Honda
Thursday at noon
Supermarket
Shopping
Parking
Blue
Color
Me
Honda
Year
Driving
In front of
Behind
1989
Section C
Ford Bronco
Parking Episode 1
Saturday at 2:00
Supermarket
Shopping
Parking
Blue
Color
Me
Honda
Year
Driving
Left of
Behind
1989
Section E
Mazda Miata
Parking Episode 2
(C)

In this section, we've explored mechanisms for forgetting or at least being unable to retrieve previously stored information. It makes sense now to ask, What happens to information that is retained instead of forgotten? Let's look now at how information from LTM is retrieved successfully.

## Retrieval of Information

Suppose you want to improve your chances of recalling information at a later date (for example, to study for an upcoming midterm in cognitive psychology). What do we know about retrieval that can help? In Chapter 9 we'll discuss a number of **mnemonics,** techniques to improve memory, many of them having to do with visual imagery. For the present, we will consider a few principles of retrieval that can be used to aid recall.

The first is the principle of categorization. This states that material organized into categories or other units is more easily recalled than information with no apparent organization. This effect happens even when organized material is initially presented in a random order.

Bousfield (1953) presented participants with a list of 60 words. The words came from four categories—animals, names, professions, and vegetables—but were presented in scrambled order. Nevertheless, participants tended to recall the words in clusters—for example, a number of animals together, then a group of vegetables, and so on. It turns out that even if the material doesn't have apparent organization, asking people to organize it into their own subjective categories improves recall (Mandler, 1967).

How can we apply the principle of categorization to your studying for a midterm? Simply put, the best advice is to categorize and organize your information! Make a list of theories of forgetting, for example, and organize your notes about memory phenomena around this list. That way, if you are asked to write an essay about theories of forgetting, you will likely recall more of the relevant information.

A second principle of retrieval, discovered by Thomson and Tulving (1970), is called **encoding specificity.** The idea is that when material is first put into LTM, encoding depends on the context in which the material is learned. The manner in which information is encoded is specific to that context. At the time of recall, it is a great advantage to have the same context information available. Aspects of the context function as cues to the retrieval.

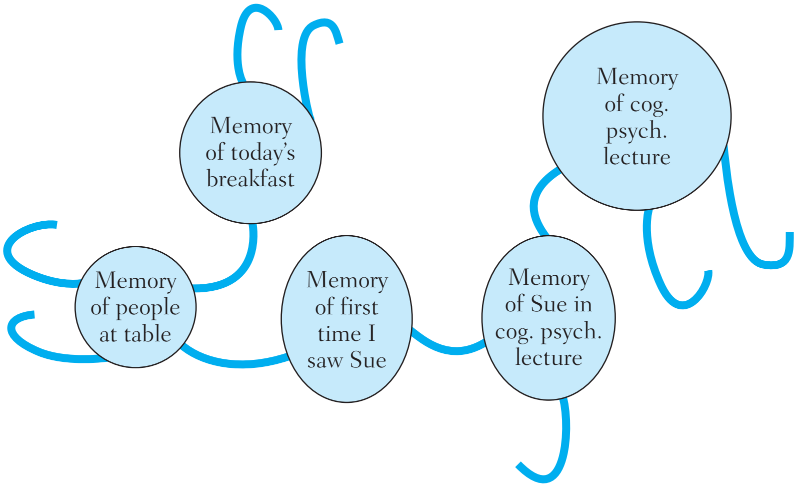
Tulving and Thomson (1973) demonstrated the encoding specificity principle as follows. Participants saw lists of words, with the to-be-remembered words printed in capital letters. Some participants saw these "target" words paired with other words printed in small letters. Both groups were told that the words in small letters were cues or hints. Cues were either highly related to the target (such as *hot–COLD*) or not very related (such as *ground–COLD*).

Participants in the control condition were presented with the target words, but no cues (such as *COLD*).

At recall, participants in the control condition (who hadn't seen any cues during the learning phase of the task) were aided if highly related cues were presented, even though these cues hadn't been seen in the learning phase. In contrast, as you might expect, the not-very-related cues were not very effective in prompting recall. However, the results were very different for participants who *had* seen cues during the learning phase. For these participants, the not-very-related cues were in fact effective in aiding recall, even better than highly related cues that had not been presented during the learning phase. Thomson and Tulving believed that even a weakly related word can become a retrieval cue if it is presented at the time of encoding.

To help your understanding of encoding specificity, you might think of material stored in LTM as a series of bubbles with hooks attached, as shown in Figure 6-6. The bubbles contain the material to be stored. The hooks represent information associated with the material. Apparently, many of these associations are formed at the time the to-be-remembered material is first encoded. If these hooks are created at encoding and are presented again at the time of attempted retrieval, the target material in the bubble is retrieved easily, by a process akin to mentally grabbing one of the hooks.

**FIGURE 6-6** ■ *Abstract depiction of long-term memory storage. Circles represent units of information. "Hooks" that are attached to the information at the initial encoding depict associations to the information and attach one unit of information to another.*


Memory of today's breakfast
Memory of cog. psych. lecture
Memory of people at table
Memory of first time I saw Sue
Memory of Sue in cog. psych. lecture

Roediger and Guynn (1996) summarized the encoding specificity hypothesis slightly differently:

> A retrieval cue will be effective if and only if it reinstates the original encoding of the to-be-remembered event. When a word like *black* is presented without context, it is presumably encoded with regard to its dominant meaning (as associated with *white*). Therefore, *white* serves as an effective retrieval cue, and a weak associate like *train* does not. However, when *black* is encoded in the context of a weak associate like *train*, subjects are likely to engage in a more idiosyncratic encoding of the target word (e.g., they might imagine a black train). In this case, the weak associate could serve as an excellent retrieval cue, but now the strong associate is completely ineffective. (p. 208)

Apparently, even information unrelated to the material, such as the environmental stimuli present at the time of encoding, can become a hook. One of my favorite studies is that by Godden and Baddeley (1975), who presented lists of 40 unrelated words to 16 scuba divers, all wearing scuba gear. Divers learned some of the lists on the shore and the others 20 feet under water. They were later asked to recall the words either in the same environment where they were learned or in the other environment. Results showed that recall was best when the environment was the same as the learning environment. Lists learned underwater were best recalled underwater, and lists learned on the shore were recalled best on the shore. This finding, that recall is best when performed in the original environment, is called a **context effect.**

Interestingly, researchers later found that recognition memory does not show the same context effect (Godden & Baddeley, 1980), suggesting that recognition and recall work differently. In particular, this finding suggests that physical context affects recall but not recognition (Roediger & Guynn, 1996). Presumably, in the former task the participant must do more work to generate his or her own retrieval cues, which may include certain features of the learning environment, whereas in the latter task, the test itself supplies some retrieval cues (in the form of the question and the possible answers).

Other studies have demonstrated similar effects (called **state-dependent learning**) with pharmacological states: Material learned while someone is chemically intoxicated (for example, by alcohol or marijuana) is usually recalled better when the person recreates that state (J. E. Eich, 1980). By the way, to ensure that you don't use this scientific finding as an excuse to party, I must note that overall performance was best for those participants who learned and recalled material while sober! However, the finding of interest was that participants who learned material while in a chemically altered state showed significantly better recall if they were again chemically intoxicated at the time of recall. Later studies suggest that this **state-dependent memory** effect, like context effect, is found only with recall and not with recognition tasks (Roediger & Guynn, 1996).

Bower (1981) even claimed that a person would recall more information if he or she were in the same mood at recall time as at encoding time. That is, Bower claimed that if you learned information while happy, you would recall that information better if you were in a happy mood again. Over the years, however, this **mood-dependent memory effect** has proven more complicated than this, although recent work suggests the phenomenon does occur under certain conditions (E. Eich, 1995).

Further support for the encoding specificity hypothesis comes from a phenomenon known as the **spacing effect** (Ross & Landauer, 1978). You may already be familiar with this effect because it restates advice that teachers often give. Simply, if you repeatedly study the same material, you are much better off with a number of short study sessions spaced some time apart than you are with one long session. (In other words, don't cram!) Ross and Landauer noted, "In most cases, two immediately successive presentations [of a piece of information] are hardly more effective than a single presentation, while two well spaced presentations are about twice as effective as one" (p. 669).

A variety of theories seek to explain the spacing effect (Glenberg, 1977; Ross & Landauer, 1978). One of the most common is called **encoding variability.** In terms of the model in Figure 6-6, spacing allows the context of encoding to change, so a wider variety of hooks can be attached to the material. The greater the number of hooks, the greater the chances of getting hold of one or more of them at the time of retrieval. Thus the spacing effect is explained primarily in terms of the encoding specificity principle.

Another concept relevant to retrieval from long-term memory is **cue overload** (Roediger & Guynn, 1996). The basic principle here is that a retrieval cue is most effective when it is highly distinctive and not related to any other target memories. For example, we all remember dramatic, unusual events better than we do routine, more mundane events.

Marigold Linton (1982) conducted a study that nicely demonstrates this principle. Like Hermann Ebbinghaus, she studied her own memory. Like those of Ebbinghaus, her methods of data collection have a heroic quality: Every day for six years (!), she wrote brief descriptions of two (or more) events that had happened that day. Each month, she conducted tests of her memory.

> Memory tests proceeded as follows: Once a month items were drawn semi-randomly from the accumulated event pool. After reading a pair of randomly paired event descriptions, I estimated their chronological order and attempted to reconstruct each item's date. Next, I briefly classified my memory search (for example, I might "count backwards" through a series of similar events, as

> school quarters, Psychonomic Society meetings, and the like) and reevaluated each item's salience. After six years the experiment had reached imposing dimensions. I had written more than 5,500 items (a minimum of two times each day) and tested (or retested) 11,000 items (about 150 items each month). Item generation required only a few minutes each day but the monthly test was extremely laborious, lasting 6–12 hours. (pp. 78–79)

Linton (1982) found that some items were easily retrievable: Any description such as "I did *X* for the first time" (for example, went to New York, met a famous psychologist) was very memorable. Other items became harder and harder to recall, especially when the written description did not pertain to a single, distinctive event.

> In 1972 I wrote an item approximately as follows: "I xerox the final draft of the statistics book and mail it to Brooks/Cole." Some years after the third "final draft" had been submitted this item was singularly nondiscriminating. Which event did I mean? Was the item written when I naively believed that the first draft would be the "final draft"? After the second submission when it was clear that the final draft now had been submitted? Or was this allusion to the third submission, which historically became the "final draft"? (pp. 82–83)

Put once again in terms of Figure 6-6, we can offer the following analogy for cue overload. Imagine a hook attached, not to one, but to several circles. Grabbing hold of that hook may lead you to an incorrect target. The more circles a given hook is attached to, the lower the probability it will link you to the correct memory.

## ■ THE LEVELS-OF-PROCESSING VIEW

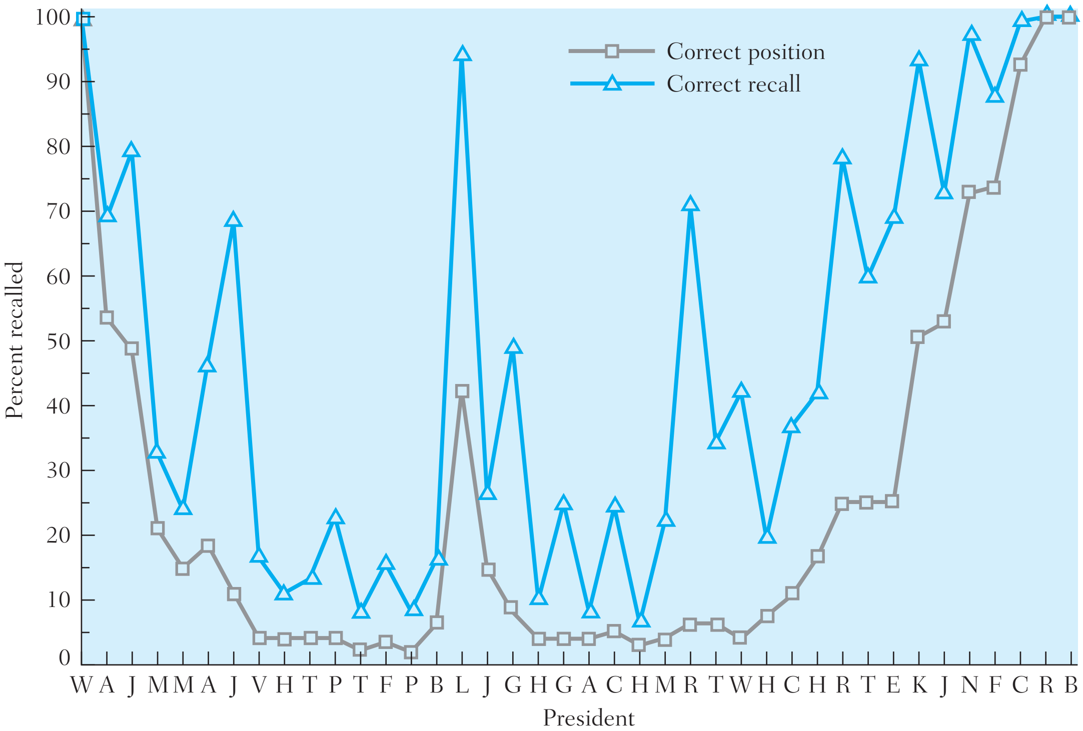
The modal approach to memory makes a distinction between different kinds of memory—for example, sensory memory, STM, and LTM stores. (Review Chapter 5 for a detailed discussion of sensory memory and STM.) Researchers think these components process information differently, store information differently, and retain information for different lengths of time. The component used at any given time depends primarily on how long information is stored.

The modal approach is not universally endorsed, however. Some psychologists argue that there is only one kind of memory storage (Melton, 1963) but that different kinds of information processing take place within that store. Others take issue with the way the modal approach describes certain kinds of memory stores, such as STM.

Crowder (1993), for example, pointed out many different experimental findings that he said were inconsistent with the modal model of STM. To cite just one: If you ask undergraduates to list the names of all the U.S. presidents they can recall, you are likely to obtain a curve such as shown in Figure 6-7. Note that its overall shape looks quite similar to a typical serial position curve; it shows both a primacy and a recency effect. But it is completely implausible to suggest that the existence of the recency effect indicates the undergraduates were drawing on STM to recall the most recent presidents. Although you might want to argue that the size of the recency effect is larger than is typically found (Healy & McNamara, 1996) or that the classic conception of STM can be extended and elaborated to account for such findings (Shiffrin, 1993), the fact remains that the modal model is no longer the only viable explanation of how memory works.

**FIGURE 6-7** ■ *Recall of the names of U.S. presidents as a function of their ordinal position.*

**SOURCE:** Crowder (1993, p. 143).



One alternative to the modal view of memory is the **levels-of-processing theory of memory.** In this model, memory is thought to depend not on how long material is stored or on the kind of storage in which the material is held, but on the initial encoding of the information to be remembered (Craik & Lockhart, 1972). That is, the levels-of-processing approach does not posit different memory stores (such as STM and LTM) but rather posits different kinds of cognitive processing that people perform when they encode information.

The fundamental assumption is that retention and coding of information depend on the kind of perceptual analysis done on the material at encoding. Some kinds of processing, done at a superficial or “shallow” level, do not lead to very good retention. Other kinds of “deeper” (more meaningful or semantic) processing improve retention. According to the levels-of-processing view, improvement in memory comes not from rehearsal and repetition but from greater depth of analysis of the material.

Craik and Tulving (1975) performed a typical levels-of-processing investigation. Participants were presented with a series of questions about particular words. Each word was preceded by a question, and participants were asked to respond to the questions as quickly as possible; no mention was made of memory or learning. Any learning that is not in accord with the participant’s purpose is called **incidental learning.**

In one experiment, three kinds of questions were used. One kind asked the participant whether the word was printed in capital letters. Another asked if the target word rhymed with another word. The third kind asked if the word fit into a particular sentence (for example, “The girl placed the _____ on the table”). The three kinds of questions were meant to induce different kinds of processing. To answer the first kind of question, you need look only at the typeface (physical processing). To answer the second, you need to read the word and think about what it sounds like (acoustic processing). To answer the third, you need to retrieve and evaluate the word’s meaning (semantic processing). Presumably, the “depth” of the processing needed is greatest for the third kind of question and least for the first kind of question.

As predicted, Craik and Tulving (1975) found that on a surprise memory test later, words processed semantically were remembered best, followed by words processed acoustically. However, the experiment gave rise to an alternative explanation: Participants spent more time answering questions about sentences than they did questions about capital letters. To respond to this explanation, in subsequent experiments the authors showed that even if the physical processing was slowed down (by asking participants, “Does this word follow a consonant-vowel-consonant-vowel-consonant-vowel pattern?”), memory was still best for more deeply processed information.

Craik and Tulving (1975) initially equated depth of processing with degree of semantic processing. But Bower and Karlin (1974), studying memory for faces, found similar results with nonverbal stimuli: Participants who rated faces for “honesty” showed better memory than participants who rated the faces according to gender. One problem with this approach, though, was pinning down the definition of what defined a level and what made for “depth” (Baddeley, 1978).

Craik and Tulving (1975) found, for instance, that the "meaningfulness" of the initial task was not the only factor that could account for better retention. Participants who were asked to determine if words fit into sentences showed poorer recall for simple sentences (for example, "She cooked the ______") than they did for more complex sentences (for example, "The great bird swooped down and carried off the struggling ______"). Levels-of-processing theory as initially formulated would argue that both words were processed semantically, so that could not account for the difference in recall. Craik and Tulving therefore extended the levels-of-processing idea, arguing that the elaboration of material could also aid recall. Presumably, the second, more complicated sentence calls to mind a richer idea: The sentence itself has more underlying propositions (there was a bird, the bird was very large, the bird swooped down, the bird carried something off) than the first sentence (there is a female, she is baking something). Sentences that specified more precisely the relation of the target word to the context were found especially likely to increase the probability of recalling the target word (Stein & Bransford, 1979).

Craik and Lockhart (1972) viewed memory as a continuum of processes, from the "transient products of sensory analyses to the highly durable products of semantic . . . operations" (p. 676). This view ties memory in with other cognitive systems quite neatly. For example, recall the work on dichotic listening tasks, reviewed in Chapter 4. Recall that material from the unattended channel is typically not remembered after the task is completed. The levels-of-processing approach can account for this finding, holding that material not analyzed for meaning receives only "shallow" processing, which results in poor retention.

Baddeley (1978) presented a thorough critique of the levels-of-processing approach. First, he argued that without a more precise and independent definition of "depth of processing," the usefulness of the theory was very limited. Second, he reviewed studies that showed, under certain conditions, greater recall of information processed acoustically than semantically. Finally, he described ways in which the modal view of memory could explain the typical levels-of-processing findings.

Nonetheless, the levels-of-processing approach did help to reorient the thinking of memory researchers, drawing their attention to the importance of the *way* material is encoded. The approach has helped cognitive psychologists think about the ways in which people approach learning tasks. It has reinforced the idea that the more "connections" an item has to other pieces of information (such as retrieval cues), the easier it will be to remember, a point that fits nicely with the idea of encoding specificity discussed earlier.

Other memory research has also encouraged psychologists to pay attention to how encoding changes with the type of material presented. Some aspects of information, for instance, seem to be encoded without much effort, or even intention. Frequency of occurrence is one such aspect (Hasher & Zacks, 1984). For example, if you are a movie fan, you see lots of movies, and you may even see some more than once. Although you probably have no reason to keep track of how many times you saw a particular movie, you may have a clear sense you've seen one a few more times than you've seen another. Chances are quite good that your sense is correct. If so, Hasher and Zacks would explain your impression as an instance of *automatic encoding:* Certain aspects of experience, such as frequency of occurrence, have a special representation and are kept track of in memory without effort or even intention.

Other work in various laboratories is aimed at explicating other so-called unitary models of memory, which do not assume different processes for short- and long-term memory. Like Craik and Tulving, psychologist James Nairne (2002) argues against positing distinct short- and long-term memory stores. What differs for memories recalled after a few seconds versus after several years, Nairne believes, are the retrieval cues that are in effect. Thus, unlike Craik and Tulving, who emphasized encoding processes, Nairne focuses instead on retrieval.

## THE RECONSTRUCTIVE NATURE OF MEMORY

Thus far, we have concentrated on laboratory studies of memory. This tradition dates back at least to Ebbinghaus. One can't help admiring Ebbinghaus's dedication and feeling gratitude for his many insights about memory. However, a similarly common reaction is to find his efforts somewhat amusing. After all, what relevance do his heroic studies have to memory in "real life"? Does the study of memory for nonsense syllables really tell us very much about how to study for an upcoming midterm, how to remember where we left our house key, or how we recall our first day of kindergarten (if in fact we remember anything about it)?

Another pioneer in the study of memory, Frederick Bartlett, rejected the emphasis on laboratory studies of memory. Bartlett (1932) believed that in the real world (as opposed to the laboratory) memory largely uses world knowledge and **schemata—**frameworks for organizing information. According to Bartlett, at retrieval time this knowledge and organizational information is used to reconstruct the material. Bartlett tested both friends and students, first presenting them with stories such as the one in Box 6-1.

Bartlett used the method of serial reproduction, meaning participants were asked to recall the stories on more than one occasion. Participants were asked to recall the tales at varying intervals, some as long as years. Bartlett was interested in what information was remembered and what information

## Box 6-1 "The War of the Ghosts": A Story Used by Bartlett (1932) to Investigate Long-Term Memory

One night two young men from Egulac went down to the river to hunt seals, and while they were there it became foggy and calm. Then they heard war-cries, and they thought: "Maybe this is a war-party." They escaped to the shore, and hid behind a log.

Now canoes came up, and they heard the noise of paddles, and saw one canoe coming up to them. There were five men in the canoe, and they said: "What do you think? We wish to take you along. We are going up the river to make war on the people." One of the young men said: "I have no arrows." "Arrows are in the canoe," they said.

"I will not go along. I might be killed. My relatives do not know where I have gone. But you," he said, turning to the other, "may go with them." So one of the young men went, but the other returned home.

And the warriors went on up the river to a town on the other side of Kalama. The people came down to the water, and they began to fight, and many were killed. But presently the young man heard one of the warriors say: "Quick, let us go home: that Indian has been hit." Now he thought: "Oh, they are ghosts." He did not feel sick, but they said he had been shot.

So the canoes went back to Egulac, and the young man went ashore to his house, and made a fire. And he told everybody and said: "Behold I accompanied the ghosts, and we went to fight. Many of our fellows were killed, and many of those who attacked us were killed. They said I was hit, and I did not feel sick." He told it all, and then he became quiet. When the sun rose he fell down. Something black came out of his mouth. His face became contorted. The people jumped up and cried.

He was dead.

**SOURCE:** Bartlett (1932, p. 67).

was "misremembered"—distorted or reordered in the participants' recollections. Box 6-2 provides examples of repeated recollections of the "War of the Ghosts" story as retold by one participant. This retelling shows concretely that over time, the same person's recall becomes more distorted.

Bartlett used this evidence to argue for a constructive view of long-term memory (LTM). He believed that participants unintentionally introduced the distortions to make the material more rational and more coherent from their own point of view. Interestingly, the original story, a Native American folktale, was often "misrecalled" in ways more consistent with people's cultural conventions for stories. Thus, the "foggy and calm" weather might be changed to a "dark and stormy night"—something more in keeping with a Western assumption of how weather portends bad events. Bartlett thus rejected the idea of LTM as a warehouse where material is stored unchanged until retrieval. Rather, he saw memory as an active and often inaccurate process that encodes and retrieves information so as to "make sense."

## Box 6-2 One Participant's Recall of "The War of the Ghosts"

*Recalled 15 minutes after hearing story:*

**The Ghosts**

There were two men on the banks of the river near Egulac. They heard the sound of paddles, and a canoe with five men in it appeared, who called to them, saying: "We are going to fight the people. Will you come with us?" One of the two men answered, saying: "Our relations do not know where we are, and we have not got any arrows." They answered: "There are arrows in the canoe." So the man went, and they fought the people, and then he heard them saying: "An Indian is killed, let us return." So he returned to Egulac, and told them he knew they were ghosts.

He spoke to the people of Egulac, and told them that he had fought with the Ghosts, and many men were killed on both sides, and that he was wounded, but felt nothing. He lay down and became calmer, and in the night he was convulsed, and something black came out of his mouth.

The people said: "He is dead."

*Recalled two weeks later:*

**The Ghosts**

There were two men on the banks of a river near the village of Etishu (?). They heard the sound of paddles coming from the up-stream, and shortly a canoe appeared. The men in the canoe spoke, saying: "We are going to fight the people: will you come with us?"

One of the young men answered, saying: "Our relations do not know where we are; but my companion may go with you. Besides, we have no arrows."

So the young man went with them, and they fought the people, and many were killed on both sides. And then he heard shouting: "The Indian is wounded; let us return." And he heard the people say: "They are the Ghosts." He did not know he was wounded, and returned to Etishu (?). The people collected round him and bathed his wounds, and he said he had fought with the Ghosts. Then he became quiet. But in the night he was convulsed, and something black came out of his mouth.

And the people cried: "He is dead."

**SOURCE:** Bartlett (1932, pp. 68–69).

Psychologist Ulric Neisser, a major figure in the study of memory, offered related arguments regarding studying memory in natural settings (1982a). Neisser was skeptical of the assumption that laboratory studies of memory are necessarily relevant to memory in natural settings; rather, he believed that laboratory studies are of limited value in understanding the use of memory in everyday life. Neisser called for the study of how people construct and use memories of their own past experiences, how they remember events of historical significance, how they use memory to plan and carry out everyday errands, and so on. In this section, we will take up some of these questions.

### Autobiographical Memory

Marigold Linton's (1975, 1982) work, described earlier, is a good example of a classic study of **autobiographical memory**—that is, memory for events that the rememberer has been part of. Recall that she spent six years in a true Ebbinghausian endeavor: studying her own recall of events from her own life. Each day she would record short descriptions of that day's events, typing them onto a 4-by-6 index card, on the back of which she recorded the actual date, as well as different ratings of the event (for example, how clearly distinguishable she believed the event would be in the future, the emotionality of the event, and the importance to her life goals of the event). At the end of the month (when 60 to 90 cards had accumulated), she would gather and randomly sort them into 14 piles for testing during the following three years. Twelve of the piles were tested in the following 12 months; the remaining sets were used two and three years after the events, respectively.

Each month, after doing a brief free recall of life events as a warm-up task, Linton shuffled all the cards due for testing that month, then exposed two cards at a time while starting a stopwatch. She recorded the cards' code numbers, then tried to order the two exposed events (that is, which happened before the other). Her time to perform this ordering was recorded. Next she restarted the stopwatch, timing how long it took to recall the exact date of the left-hand card. Finally, she did the same for the right-hand card.

During the first 20 months of the study, Linton recorded 2003 events and tested 3006 (1468 of these were retests of previously tested items). She had expected, before running the study, that she would quickly forget many of the items, but in fact that did not happen, perhaps because she needed only to recognize the events (not recall them) and to date them, not answer detailed questions about them. In fact, Linton's results suggested that real-world memories are much more durable than those of most laboratory experiments.

Linton also recorded protocols of herself thinking aloud (a technique discussed in Chapter 11) as she tried to date items. She found that she often used problem-solving strategies to arrive at a date, even when she had no explicit recall of the event. You might be able to re-create this phenomenon by trying to answer the following question: Where were you on June 28, 2005, at 11:20 A.M.? Your first reaction may be to laugh and to claim you can't possibly answer the question. But think about it. No doubt you can find some "markers" that point you toward some sort of answer. For instance, you might note that June is during the summer. You might be able to figure out June 28 must have been a Tuesday, because (say) your mother's birthday is June 25, and you remember that being on a Saturday. You might remember you held a summer job at a local department store and conclude that at 11:20 on June 28, you must have been working, probably stocking shelves. Notice that what you've done is to "zero in" on the date and time by finding and using different "markers." You haven't necessarily remembered what you were doing; instead, you've reconstructed it.

Linton also reported on "unrecalled" items and found them to be of (at least) two types. Some were simply not recalled; that is, the description she originally reported did not serve to bring to mind any recollection of the event when it was tested. However, at least as many "forgotten" items were ones Linton found herself unable to distinguish from other, similar memories.

Robinson and Swanson (1990) offered an explanation of Linton's findings on "unrecalled" items. They suggested that as similar events are repeated, the similar aspects start to form an event schema. That is, as Linton repeatedly experienced an event, such as sending what she believed to be a "final" draft of her book to her publisher, memory traces of the specific instances of the different events fused together and became indistinguishable. Linton herself (1982) talked about a transformation from episodic to semantic memory, a topic we will take up in the next chapter.

Barsalou (1988) reported findings consistent with Robinson and Swanson's (1990) proposal. He and his collaborators stopped people on the campus of Emory University during the fall semester and asked whoever agreed to participate to describe events they were involved with during the preceding summer. Although people were asked to report and describe specific events, only 21% of the recollections collected could be categorized as specific recollections. Instead, people were more likely to give "summarized events," statements that referred to two or more events of a certain kind, such as "I went to the beach every day for a week." These summarized events made up almost a third of the recollections collected. People also reported what Barsalou called an "extended event," a single event lasting longer than a day, such as "I worked at a camp for disadvantaged children." Even when Barsalou and his associates pointedly tried to elicit only specific event recollections, their participants still tended to report extended or summarized events.

Brewer (1988) took a different methodological approach to studying recall for ordinary events. He found eight very cooperative undergraduates to serve in a demanding multiweek experiment. During the data acquisition phase, participants were asked to wear beepers programmed to go off on a random schedule about once every two hours. When the beeper sounded, participants were asked to fill out a card with information about the event that had occurred when the beeper went off. Specifically, participants were asked to report the time and their location, actions, and thoughts and then to complete a number of rating scales (rating such things as how often this kind of event occurred, how pleasant the event was, and how trivial or significant). Fortunately, participants were given the option of recording the word "private" on a card instead of giving a detailed account, if the activity they were engaged in was one they preferred for any reason not to report. Brewer noted that most participants exercised this option at least occasionally, which no doubt led to some systematic undersampling of certain kinds of events, such as dating or parties.

Brewer (1988) argued that this methodology had certain advantages over the one Linton used. Obviously, it involves separating the experimenter from the participant, which methodologically has many advantages. More important, however, Brewer argued that Linton wrote down the most "memorable" events of each day, which would tend to skew the set of items to be remembered. Brewer compares Linton's technique to one in which a laboratory participant in an experiment is given lists of hundreds of words each day and is asked at the end of each day to select one word to use in later testing. To compare these techniques, Brewer also asked his participants to list the most memorable event of each day.

Brewer (1988) later tested his participants' recall of the events they had recorded on cards. Each participant was tested three times: once at the conclusion of the data acquisition period, once about 21.2 months later, and once about 41.2 months after the end of the acquisition period. Items tested were randomly selected from all items the participants had initially described.

Brewer (1988) reported very good overall retention from his participants, who recognized more than 60% of the events. Memory was better for actions than for thoughts, and better for "memorable" events than for events randomly prompted by beepers. Consistent with some of the results Linton reported (1975, 1982), Brewer found that events that occurred in a unique or infrequent location were better remembered than occurrences in frequented locations. Similarly, rare actions were more likely to be recalled than frequent actions. Interestingly, the time period of study encompassed the Thanksgiving break for Brewer's participants. Memories from that minivacation were recalled especially well. The reason for this, Brewer argued, was that these trips were taken during the participants' first trip home from college (all the participants were first-year students). Those trips, he believed, were likely to be quite distinctive, especially in comparison with the routine events of going to class and studying that preceded and followed the vacation. Brewer concluded that the more distinct the mental representation of an event, the more likely it is to be recalled, a conclusion similar to the one Linton reached.

In summary, Brewer (1988) concluded that autobiographical memories, while showing many of the phenomena demonstrated in laboratory studies, also showed important differences. Few overt recall errors were found, suggesting to Brewer that "personal memories are reasonably accurate copies of the individual's original phenomenal experiences" (p. 87).

## Flashbulb Memories

Where were you when you learned of the terrorist attack on the World Trade Center on September 11, 2001? Many of us recall information not only about

Nancy J. Ashmore

*Autobiographical memories include recollections of events both mundane and important. What do you remember about the time you first met your college roommate?*

the tragic disaster itself but also about where we were, whom we were with, and what we were doing at the time we first heard about it. For example, I was standing in line at Goodbye, Blue Monday, my town's local coffee store. I'd just had my hair done, and was thinking about all the things I had to do that day, when a woman in a pink dress behind me tapped me on the arm and asked if I'd heard the news. When I got to my car, I turned on the radio, and hurried into school to use my computer to surf the web. For most of the day I listened to the radio, surfed the web, and talked in horrified tones to coworkers. That evening, I took my 8-year-old son to an on-campus service of remembrance. The day seems etched permanently in my memory.

Brown and Kulick (1977) coined the term **flashbulb memory** to describe this phenomenon. Other examples might be found in your parents' or other relatives' recollections of where they were when they heard about the assassinations of John F. Kennedy or Martin Luther King, Jr. A recent study reports on flashbulb memories among Danish World War II veterans of the invasion and liberation of Denmark (Berntsen & Thomsen, 2005). Given the historical importance and surprising nature of these events, it may be small wonder that most of us old enough to have experienced them remember them. Why, though, do we remember details about our own circumstances when we first heard the news? Some have argued that part of the explanation involves our physiological response when we hear such news: Parts of the brain that are involved in emotional responses activate, and the cognitive effects of this activation result in the storage of a great deal of information only indirectly related to the main information (Brown & Kulik, 1977). Pillemer (1984) found, for example, that his participants who reported a stronger emotional reaction to the news of the assassination attempt on President Reagan had stronger and more detailed flashbulb memories.

AP/Wide World Photos

*The 9/11 attacks were events that easily led to the formation of flashbulb memories.*

Neisser (1982b) offered a different explanation for the origin of flashbulb memories: People are finding a way to link themselves to history. Flashbulb memories come about because the strong emotions produced by the event prompt people to retell their own stories of where they were when they heard the news. Flashbulb memories, then, result from the retellings of stories. Over time, the memories can become distorted, in much the same way that participants in Bartlett's (1932) study distorted their retellings of the "War of the Ghosts" story: People elaborate and fill in gaps in their stories, making them approximate a standard story format.

Stephen Schmidt (2004) offered results of a study on people's flashbulb memories for 9/11. Undergraduates at his university (Middle Tennessee State) filled out survey instruments asking for their recall of the events of 9/11, beginning the very next day (9/12/2001). Students were also resurveyed two months later. In this way, Schmidt was able to compare recollections across a two-month time span. Almost all of his participants were able to report basic "flashbulb" information: who told them about 9/11, where they were when they first heard the news, what activity they were engaged in when they first heard the news, what they were wearing, what the weather was like. Students showed greater consistency in answering what Schmidt calls "central" questions, such as the first three in the list above, and less for "peripheral" questions, such as what they were wearing. However, contrary to prediction, Schmidt found that those participants who initially reported the strongest emotional reaction to the events of 9/11 showed the most impairment in their memory. Interestingly, Daniel Greenberg (2004) analyzed news reports to show that George W. Bush has demonstrated substantial inaccuracies in his own flashbulb memories of the events of that day. Arguably, as the sitting president during the events of 9/11, his reaction was powerfully emotional.

The question of whether flashbulb memories differ in kind from other types of memories has been actively debated (see, for example, Cohen, McCloskey, & Wible, 1990; McCloskey, Wible, & Cohen, 1988; Pillemer, 1990). McCloskey et al. (1988), for example, found evidence that some flashbulb memories are quite inaccurate and that the kinds of forgetting and distortion evident in flashbulb memories can be predicted on the basis of traditional studies of ordinary memory.

Weaver (1993) reported on a relevant and well-timed study of flashbulb memories. In January 1991, Weaver asked students enrolled in an upper division psychology class to try to remember, in detail, their very next meeting with their roommate (or friend, if they were living alone). Specifically, students were urged to do their best to remember "all the circumstances surrounding" that meeting (without being told specifically what kinds of things to try to remember). Weaver's intention was to see whether the memories formed of these routine meetings would function in ways similar to flashbulb memories, and he distributed a sealed questionnaire for students to fill out as soon as feasible after the meeting.

As it happened, that very evening the first President Bush announced the initial attacks on Iraq in the Persian Gulf War. Although expected and thus not terribly surprising, it was an event of great consequentiality, especially to people with friends or relatives involved. Thus this event seemed likely to be one for which flashbulb memories would be formed. Weaver, reacting quickly, created another questionnaire asking about their memories of hearing about Bush's announcement. Students filled out this second questionnaire two days later. Weaver (1993) gave similar questionnaires about both memories (bombing of Iraq and meeting with roommate/friend), which students completed in April 1991 (three months after the original events) and January 1992 (one year after the original events).

Weaver found very few differences in accuracy for the two memories (as measured by the degree of correspondence between the January 1991 descriptions and the two subsequent ones). Weaver reported that accuracy for both fell off in an Ebbinghaus-like pattern: less accuracy after 3 months, but relatively little change from 3 months to 12 months. What did differ, however, was students' confidence in their memories. Students were much more confident in their memories of the Persian Gulf bombing than in their memory for meeting their friend or roommate. However, the increased confidence did not lead to increased accuracy.

Weaver (1993) concluded that no "flash" is necessary to form a flashbulb memory: Having an intention to remember a particular meeting or event seems enough to ensure forming some memory of it. The "flash," he concluded, affects only our confidence in our memory. What makes flashbulb memories special, he argued, is in part the "undue confidence placed in the accuracy of those memories" (p. 45). Although this last assertion is sure to be controversial, probably no cognitive psychologist would disagree with another of Weaver's conclusions: "Flashbulb memories for exceptional events will continue to be studied, for obvious and interesting reasons. They are rare, unique, and universal" (p. 45). However, Weaver and others reject the idea that flashbulb memories rely on special memory mechanisms.

## Eyewitness Memory

Imagine yourself a juror assigned to a robbery/murder case. The defendant, a young man, is alleged to have robbed and killed a convenience store clerk at gunpoint at around 11 P.M. No physical evidence (such as fingerprints or fiber samples) links the defendant to the crime. Instead, the case hinges on the sworn testimony of a convenience store patron who insists that the defendant is the man she saw on the night in question. In cross-examination, the defense attorney gets the witness to agree that the lighting was poor, the robber was wearing a stocking cap over his face, she was nervous and paying more attention to the gun than to the face of the robber, and so on. Nevertheless, the witness remains convinced that the defendant is the man she saw that night rob and murder the store clerk.

How much would the eyewitness testimony convince you of the defendant's guilt? Elizabeth Loftus, a cognitive psychologist specializing in the study of **eyewitness memory,** would argue that the testimony would have a disproportionate effect on your behavior. She stated (Loftus, 1979) that "eyewitness testimony is likely to be believed by jurors, especially when it is offered with a high level of confidence," even when the confident witness is inaccurate. Indeed, she believed that "all the evidence points rather strikingly to the conclusion that there is almost nothing more convincing than a live human being who takes the stand, points a finger at the defendant, and says 'That's the one!'" (p. 19). Several studies Loftus reviewed, however, suggest that confidence in eyewitness testimony may be far too strong.

In one study, for example, participants viewed a series of slides depicting a (simulated) automobile accident. The automobile, a red Datsun, came to either a stop sign (for half the participants) or a yield sign (for the other half) before becoming involved in an accident with a pedestrian. The experimental

Dennis MacDonald/PhotoEdit

*Although eyewitness testimony often has dramatic effects on jurors' decision making, research suggests it is not always accurate.*

manipulation came in the questioning that followed the slide show. About half the participants (half of whom had seen a stop sign; the other half, a yield sign) were asked, “Did another car pass the red Datsun while it was stopped at the stop sign?” The other half of the participants were asked, “Did another car pass the red Datsun while it was stopped at the yield sign?” After answering these and other apparently routine questions, participants worked on an unrelated activity for 20 minutes. Then they were given a recognition test of several slides. Included in the test was a critical test pair depicting a red Datsun stopped either at a stop sign or at a yield sign. Participants were to decide which of the two slides they had originally seen. Those who received a question consistent with the slide originally seen (for example, a question about the stop sign when the slide they had previously seen contained a stop sign, not a yield sign) correctly recognized the slide 75% of the time. Participants who received an inconsistent question, however, had an overall accuracy rate of 41%, a dramatic decrease given that guessing alone would have produced an overall accuracy rate of 50%.

Other studies by Loftus (1975) have demonstrated that people’s memories can apparently be altered by presenting misleading questions. For example, some participants viewed a film and were then asked, “How fast was the white sports car going when it passed the barn while traveling along the country road?” Other participants were merely asked, “How fast was the white sports car going while traveling along the country road?” Actually, no barn was presented in the film. One week later, all participants were asked whether they had seen a barn. Fewer than 3% of the participants in the second condition reported having seen a barn, whereas 17% of the participants who had been asked the misleading question reported having seen a barn. Lane, Mather, Villa, and Morita (2001) found that experimental “witnesses” who were asked to focus on specific details of a videotaped crime were more likely to confuse what they’d witnessed with the information given them in postevent questions than were “witnesses” asked only to summarize the major aspects of the crime.

“Memory malleability” fits well with some laboratory studies of sentence recall; both support Bartlett’s conception of memory as a constructive process. A classic study by Bransford and Franks (1971) illustrates this idea. They gave participants a list of sentences, all derived from four basic sentences, such as “The ants were in the kitchen,” “The jelly was on the table,” “The jelly was sweet,” and “The ants ate the jelly.” The sentences the participants saw included two of the preceding sentences, combinations of two of the simple sentences (for example, “The sweet jelly was on the table”), and combinations of three of the simple sentences (example, “The ants ate the sweet jelly on the table”). On a later recognition test, the participants were asked to decide, for each sentence presented, if they had seen that exact sentence before and to rate their confidence in their judgment. They were most confident in "recognizing" the sentence that combined all four of the simple sentences, "The ants in the kitchen ate the sweet jelly that was on the table," even though it had never been presented.

Bransford and Franks (1971) explained that the participants had not stored a copy of the actually presented sentences in memory. Instead, they had abstracted and reorganized the information in the sentences, integrating the ideas and storing the integration. The participants later could not distinguish between the presented sentences and their own integration. One might argue this is just what Loftus's participants were doing: integrating the original memories with later questions. If the later questions were misleading, that incorrect information became integrated with the original memory to produce a distorted memory.

Recent work in cognitive psychology laboratories has focused on how to improve the chances of accuracy in eyewitness identification. Wells (1993) reviewed some of the findings and made specific suggestions on how police might set up lineups and photo lineups so as to reduce the chances of eyewitness error. For example, he suggested having "mock" witnesses, people who were not present during the crime but who have been given limited information about the crime. The logic here is that the mock witnesses should be equally likely to choose any of the people in a lineup. If, however, the mock witnesses all "identify" the actual suspect, that gives some evidence that the lineup has been put together in a biased way. Other investigators have offered other suggestions for how to decrease eyewitness suggestibility (Chambers & Zaragoza, 2001), such as warning people against being misled by tricky questions.

However, there remains active and often very sharp debate over how well the findings of laboratory studies can be extrapolated to real-world settings. Typically, research participants view staged events, or even movies or slides of incidents. This may not be very similar to the situation in which a bystander observes an actual robbery, assault, murder, terrorist attack, or other kind of crime. Moreover, it seems quite possible that victims or possible victims of crime may attend to different aspects of the situation than bystanders. Yuille (1993) argued that we need more justification to assume that research participants are subject to the same influences as witnesses (or victims) of real crimes.

## The Recovered/False Memory Debate

One of the biggest debates to erupt in cognitive psychology in recent years concerns issues of forgetting, retrieving, and creating autobiographical memories. The debate has far-reaching implications well beyond the boundaries of an experimental laboratory. At stake are issues that touch, and indeed tear apart, the lives of real people. The issues concern whether victims of abuse can and/or do repress memories of incidents of abuse, retrieving these so-called **recovered memories** later in therapy, or whether instead some therapists (in fact, a small minority), misinformed about the workings of memory, inadvertently prompt their clients to create **false memories** of things that never really happened.

Note that the topics of eyewitness testimony and false versus recovered memory share many similarities: Both essentially involve the alleged witnessing of an event, sometimes traumatic, often followed later by newer, distorting information. But differences between the topics should also be kept in mind. In the case of eyewitness testimony, the issue is typically focused on recall for information acquired within the past days, weeks, or months. In the case of false or recovered memories, the issue is whether one can recall information from several years to several decades earlier.

Elizabeth Loftus is again an active participant in the debate over whether such "recalls" represent recovered or false memories. She began a review article (Loftus, 1993) on the phenomenon with an anecdote:

> In 1990, a landmark case went to trial in Redwood City, California. The defendant, George Franklin, Sr., 51 years old, stood trial for a murder that had occurred more than 20 years earlier. The victim, 8-year-old Susan Kay Nason, was murdered on September 22, 1969. Franklin's daughter, Eileen, only 8 years old herself at the time of the murder, provided the major evidence against her father. What was unusual about the case is that Eileen's memory of witnessing the murder had been repressed for more than 20 years.
>
> Eileen's memory did not come back all at once. She claimed that her first flashback came one afternoon in January 1989 when she was playing with her 2-year-old son, Aaron, and her 5-year-old daughter, Jessica. At one moment, Jessica looked up and asked her mother a question like, "Isn't that right, Mommy?" A memory of Susan Nason suddenly just came back. Eileen recalled the look of betrayal in Susie's eyes just before the murder. Later, more fragments would return, until Eileen had a rich and detailed memory. She remembered her father sexually assaulting Susie in the back of a van. She remembered that Susie was struggling as she said, "No, don't" and "Stop." She remembered her father saying "Now Susie," and she even mimicked his precise intonation. Next, her memory took the three of them outside the van, where she saw her father with his hands raised above his head with a rock in them. She remembered screaming. She remembered walking back to where Susie lay, covered with blood, the silver ring on her finger smashed.
>
> Eileen's memory report was believed by her therapist, by several members of her family, and by the San Mateo district attorney's office, which chose

> to prosecute her father. It was also believed by the jury, who convicted George Franklin, Sr., of the murder. The jury began its deliberations on November 29, 1990, and returned its verdict the next day. Impressed by Eileen's detailed and confident memory, they found her father guilty of murder in the first degree. (p. 518)

Loftus went on in her article to examine various questions—among them, how authentic recovered memories are. The idea that memories of traumatic events can be repressed—buried in the unconscious mind for long periods of time, even forever—is a tenet of psychoanalytic forms of therapy dating back to Freud. But from a cognitive psychology perspective, the question is whether such **repressed memories** can be carefully described, documented, and explained.

Loftus (1993) and Lindsay and Read (1994) pointed to advice given in different self-help books, one of the best known being *The Courage to Heal* (Bass & Davis, 1988). That book encourages readers who are wondering whether they have ever been victims of childhood sexual abuse to look for the presence of various symptoms, such as having low self-esteem, depression, self-destructive or suicidal thoughts, or sexual dysfunction. The problem, Lindsay and Read (1994) noted, is that these symptoms can also occur for people who have *not* been victims of abuse; the symptoms are just not specific enough to be diagnostic. In *The Courage to Heal,* Bass and Davis (1988) make a further, very strong claim: "If you are unable to remember any specific instances [of abuse] like the ones mentioned above but still have a feeling that something abusive happened to you, it probably did" (p. 21) and "If you think you were abused and your life shows the symptoms, then you were" (p. 22). The book goes on to recommend that readers who are wondering about their past spend time exploring the possibility that they were abused. It offers techniques for recalling specific memories, such as using old family photographs and giving the imagination free rein, or using a recalled childhood event as a beginning point and then deliberately trying to remember abuse connected with that event.

We have seen earlier that there is plenty of room to doubt the absolute accuracy of people's autobiographical memories, even when people seem very sure of them. Research on eyewitness memory has shown how receptive people can be to postevent suggestions. But is it possible for false "memories"—of events that never happened—to be somehow implanted? Loftus and Pickrell (1995; see also Loftus & Ketcham, 1994, and Loftus, 2000) reported on a study that suggests just such a possibility.

Twenty-four people served as the target research participants. Experimenters first interviewed relatives of the participants (who, to be included in the study, had to be familiar with the participant's early childhood) and from the interviews generated three true events that had happened to the research participant when the latter was age 4 to 6. Relatives were instructed that these events were not to be "family folklore" or to be so traumatic that they would be effortlessly recalled. Relatives also provided details about shopping malls and favorite treats of the research participant when he or she was a 5-year-old.

From the interviews with relatives, experimenters then created false accounts of an event that had never actually happened, in which the target participant had allegedly become lost in a shopping mall at age 5. Included in the accounts were details about the name of the mall that had been the closest one to the participant then, as well as names of family members who plausibly might have accompanied the target participant on the alleged trip. Here is an example of a "false memory" created for a 20-year-old Vietnamese American woman:

> You, your mom, Tien, and Tuan all went to the Bremerton K-Mart. You must have been 5 years old at the time. Your mom gave each of you some money to get a blueberry Icee. You ran ahead to get into the line first, and somehow lost your way in the store. Tien found you crying to an elderly Chinese woman. You three then went together to get an Icee. (Loftus & Pickrell, 1995, p. 721)

Participants were given booklets containing instructions, and four stories. Three of the stories recounted actual events, and the fourth story recounted the false event. Each event was described in about a paragraph, with room left for the participant to describe his or her own recall of the event. One to two weeks later, the participants were individually interviewed about their recollections (again being asked to recall as much as they could about the four "events"); the participants were reinterviewed about two weeks later.

As a group, research participants recalled 68% of the true events. However, when completing the booklets, 29% of the participants (7 out of the 24) "recalled" the false event of being lost in a shopping mall. One of the seven later said she did not recall the false memory at the first interview, but the rest (6, or 25%) maintained at least partial recall of the false event through both interviews. Participants' length of recall (measured in number of words they used to describe events) was higher for the true than for the false memories, and they rated the clarity of their memories as lower for the false than for the true memories.

Loftus and Pickrell (1995) made no explicit claims about how easy it is to induce false memories or about how prevalent such memories are. They took the results as proof that false memories *can* be formed through suggestive questioning, and they offered a speculative account of the mechanism(s) responsible.

> The development of the false memory of being lost may evolve first as the mere suggestion of being lost leaves a memory trace in the brain. Even if the information is originally tagged as a suggestion rather than a historic fact, that suggestion can become linked to other knowledge about being lost (stories of others), as time passes and the tag that indicates that being lost in the mall was

> merely a suggestion slowly deteriorates. The memory of a real event, visiting a mall, becomes confounded with the suggestion that you were once lost in a mall. Finally, when asked whether you were ever lost in a mall, your brain activates images of malls and those of being lost. The resulting memory can even be embellished with snippets from actual events, such as people once seen in a mall. Now you "remember" being lost in a mall as a child. By this mechanism, the memory errors occur because grains of experienced events or imagined events are integrated with inferences and other elaborations that go beyond direct experience. (p. 724)

Other researchers have also been able to induce "recollections" of events that never happened. Hyman, Husband, and Billings (1995), for instance, were able to induce about 25% of their undergraduate participants to falsely "recall" different childhood events: being hospitalized for an ear infection; having a fifth birthday party with pizza and a clown; spilling punch at a wedding reception; being in the grocery store when sprinklers went off; and being left in a parked car, releasing the parking brake, and having the car roll into something. Garry and Wade (2005) induced false memories with both narratives and (doctored) photographs, finding that the narratives were more effective in inducing false memories.

Clancy, Schacter, McNally, and Pittman (2000) reported a study in which a laboratory-based model of a false memory was induced. They made use of what is called the Deese/Roediger–McDermott paradigm, in which a participant is presented with a number of related words—for example, *nap, bed, quiet, dark, snore, dream, pillow, night.* Later, the person is given a recognition test consisting of both these "old" words, and some "new" ones that weren't on the list. Results show that semantically related words, such as *sleep,* are likely to be falsely recognized by up to about 80% of college student participants (Roediger & McDermott, 1995).

Clancy et al. (2000) recruited four groups: a control group of women who had never experienced childhood sexual abuse (CSA); a group of women who had experienced CSA and who had a continuous memory of it; a group of women who believed they had experienced CSA but had no specific memory of it (the "repressed memory" group); and a group of women who claimed to have repressed and then recovered memories of experienced CSA (the "recovered memory" group). The recovered-memory group showed much higher false recognition of the semantically related words than did all other groups. The authors concluded:

> Our experiment concerns false recognition for nontraumatic events; therefore, care must be taken when extrapolating our findings to clinical settings. However, the results are consistent with the hypothesis that women who report recovered memories of sexual abuse are more prone than others to develop certain types of illusory memories. (p. 30)

Not all cognitive psychologists have received the research just described on false memories with complete enthusiasm, however. Pezdek (1994), for example, has argued that just because an explanation exists for how false memories *could* be formed does not mean that false memories, especially for ones as traumatic as childhood abuse, actually *are* formed in this way. By analogy, Pezdek noted that an aeronautical engineering explanation exists for why it is impossible for bumblebees to fly (even though they obviously do). Pezdek cautioned against assuming that "memory recovery therapy" is very widespread and argued that the existing evidence for therapist-implanted memories is quite weak.

In further empirical work, Pezdek and her associates (Pezdek, Finger, & Hodge, 1997; Pezdek & Hodge, 1999) suggested there are limits on the types of memories that can be suggestively implanted. Specifically, they believe events can be implanted only to the degree that there exists "script-relevant" knowledge of the type of event.

In one study, for example, Pezdek et al. (1997) recruited both Catholic and Jewish participants. For each participant, they created false accounts of a Catholic ritual (receiving communion at Mass) and one of a Jewish ritual (participating in Shabbat prayers and ceremony). Neither account included "giveaway" words, such as *host, Mass, challah* (bread), or *menorah*. The prediction was that Catholic participants would not have scripts for Jewish ceremonies and thus that implanting of a false "Shabbat" memory would be much less likely than implanting of a false "communion" memory, with the converse being true for Jewish participants. Again, this is because Catholic participants (recruited from a Catholic high school) could reasonably be expected to have a script for Catholic, but not Jewish, ceremonies, and vice versa for the Jewish participants (recruited from a Jewish high school and from Jewish religious education classes).

Indeed, these were the findings reported. Of 29 Catholic participants, 7 falsely recognized the false Catholic event, compared with only 1 who falsely recognized the false Jewish event. Conversely, 3 (of 32) Jewish participants falsely recognized the Jewish event, and none falsely recognized the false Catholic event. Replicating Loftus and Pickrell's (1995) results, significantly more words were written in the "recalls" of true than of false events, ratings of clarity of the memories were higher for true than for false events, and participants were more confident that with more time they would be able to recall more details about true than about false events (for those who "recalled" false events). Pezdek et al. (1997) argued that these results set boundaries around what kinds of events can be planted in memory, with specific instances of familiar events being particularly susceptible.

Obviously, much more work needs to be done on the issue of whether, how, and when false information can be made a part of one's memory. Loftus and

Pickrell's (1995) and Hyman et al.'s (1995) work is suggestive and provocative, but the question of to what degree they can be generalized remains open. A recent fMRI study (Cabeza, Rao, Wagner, Mayer, & Schacter, 2001) showed that different areas of the brain become activated in a word recognition task with "false" words (ones that were not presented but are semantically related to the "true" words that were). Nonetheless, the extension of findings from word recognition tasks to real-world narrative memory recalls may not be straightforward.

It is becoming clearer to cognitive psychologists that autobiographical memories do not function the way videocameras do, faithfully recording details and preserving them for long-term storage and later review. Instead, human memories are malleable and open to "shaping" by later questioning or information. Just how often such shaping occurs, and by what mechanisms, remain open and exciting questions with important real-world implications and consequences.

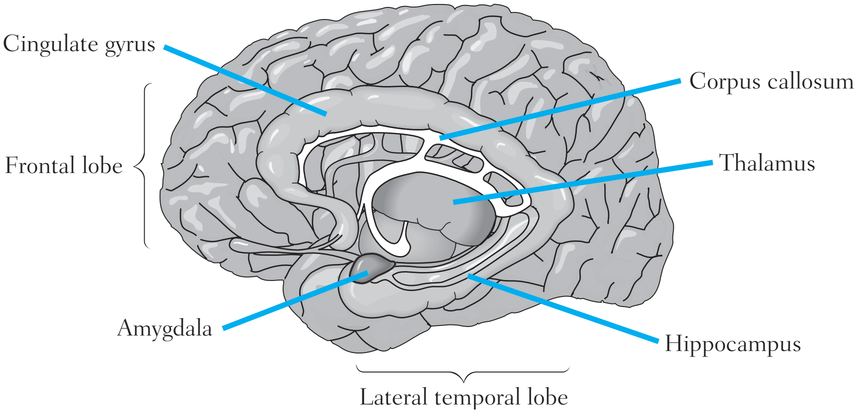
## ■ AMNESIA

In the preceding sections, we discussed material forgotten from LTM. Here, we pause to take a more detailed look at cases in which people suffer profound impairments in their LTM—people suffering from memory disorders collectively known as **amnesia.** In Chapter 5, we discussed the clinical case study of H.M., a patient who underwent surgery in 1953 that removed many brain structures in the medial temporal lobe region of the brain bilaterally (on both sides), including most of the **hippocampus,** the **amygdala,** and some adjacent areas. As a result, H.M. has suffered since that date from profound amnesia, both for any events after the surgery (anterograde amnesia) and for events that happened within a span of several years before the surgery (Schacter, 1996).

H.M. is not the only person to suffer from amnesia, of course, and over the years neurologists and psychologists have amassed a great number of clinical cases from which to draw generalizations and principles. Amnesia can result from damage either to the hippocampal system (which includes the hippocampus and amygdala) or to the closely related midline diencephalic region (see Figure 6-8). This damage can arise from oxygen deprivation, blockage of certain arteries through a stroke, the herpes simplex encephalitis virus, a closed head injury such as those typically suffered in automobile accidents, Alzheimer's disease, Korsakoff 's syndrome (a disease of chronic alcoholism), certain tumors, or, in the short term, bilateral electroconvulsive shock treatments, or ECT (Cohen, 1997).

**FIGURE 6-8** ■ *The network of neural structures underlying our ability to remember and learn. Illustrated here are the structures in the medial temporal lobe, specifically the hippocampal system (which includes the hippocampus, the amygdala, and adjoining cortex) and the midline diencephalic structures, specifically the dorsomedial nucleus of the thalamus, which, when damaged, causes amnesia. For reference, structures outside the system but located nearby (for example, the corpus callosum and the frontal region) are also shown.*

**SOURCE:** Cohen (1997, p. 319).



The severity of the amnesia varies from case to case, with H.M. exhibiting some of the most severe memory impairments. Some patients recover some memories over time; for example, those undergoing bilateral ECT (a treatment used today for severe forms of depression) recover completely within a few months, and people who suffer a closed head injury likewise often recover some or all of their memories. Some amnesias, such as those brought on by accidents or strokes, have very sudden onsets; others, typically those originating through brain tumors or disease, appear more gradually (Cohen, 1997). Many neuropsychologists make a distinction between anterograde and retrograde amnesia in terms of the way each functions, and we will therefore review each of these in turn.

## Anterograde Amnesia

Cohen (1997) noted that the **anterograde** form of amnesia, a memory deficit extending forward in time from the initial point of memory loss, has five principal features. The first is that anterograde amnesia affects LTM but not working memory. We discussed this idea in Chapter 5 in our look at the H.M. case study. Cohen related an illustrative anecdote about a conversation he had with H.M.

> One day during a lengthy car drive to MIT's Clinical Research Center to be tested, H.M. proceeded to tell me about some guns that were in his house (actually, he had them only in his youth). He told me that he had two rifles, one with a scope and certain characteristics, and the other with just an open sight.
>
> He said that he had magazines from the National Rifle Association (actually, just a memory of his earlier family life), all about rifles. But, he went on, not only did he have rifles, he also had some handguns. He had a .22, a .32, and a .44. He occasionally took them out to clean them, he said, and had taken them with him on occasion to a shooting range. But, he went on, not only did he have some handguns, he also had rifles. He had two rifles, one with a scope and the other with an open sight. He had magazines from the National Rifle Association, all about rifles, he said. But, not only did he have rifles, he also had handguns. . . . On and on this went, cycling back and forth between a description of the rifles and a description of the handguns, until finally I derailed the conversation by diverting his attention. (p. 323)

Cohen argued that H.M.'s memory of his handguns and of his rifles were both intact because they derived from his very remote past, several years before his surgery. They were related in his LTM—not surprising, given what researchers know about memory for general knowledge (a topic we will take up in Chapter 7 in greater detail). Thus his discussion of one piece of knowledge called to mind the other. Each piece, however, filled up the working-memory capacity, so that when H.M. finished talking about one, he forgot he had just told about the other.

The second feature is that anterograde amnesia affects memory regardless of the modality—that is, regardless of whether the information is visual, auditory, kinesthetic, olfactory, gustatory, or tactile. Cohen (1997) noted that global anterograde amnesia results from bilateral damage to the medial temporal lobe or midline diencephalic structures; unilateral (one-sided) damage to these areas typically impairs only one kind of memory—for example, either verbal or spatial. Moreover, whether the mode of testing memory is free recall, cued recall, or recognition, the memory of someone with anterograde amnesia is similarly hampered.

Third, according to Cohen (1997) and as illustrated in the story about H.M. and the guns, anterograde amnesia spares memory for general knowledge (acquired well before the onset of amnesia) but grossly impairs recall for new facts and events. Thus H.M. could not report any personal event that had occurred after his surgery, and he performed very poorly on tasks in which he was asked to recall lists of words for any length of time beyond a few minutes. H.M. also had difficulty retaining newly learned pairings of information, such as learning new vocabulary (*jacuzzi, granola,* and other words that came into usage after 1953, the year of his surgery).

A fourth principal feature of anterograde amnesia is that it spares skilled performance. Recall the story of the musician Clive Wearing, described in Chapter 5, who cannot remember much of his own life or remember his wife's frequent visits but can still play the harpsichord and piano and conduct a choir through a complex piece of music. Other studies have shown that amnesic patients can be taught to perform a skill, such as mirror tracing (tracing the outline of a geometric figure that is only visible in a mirror) or a rotary pursuit task (tracking a target that is moving circularly and erratically). H.M. learned the first task and showed a normal learning curve for it, although at each session he denied any previous experience with the task. Cohen and Squire (1980) have shown similar results in teaching amnesic patients and nonamnesic control participants to perform a mirror-image reading task. As the data presented in Figure 6-9 show, the data from the amnesic patients were in many instances virtually identical to those of the control participants.

The fifth principal feature of anterograde amnesia is that even when amnesic patients do learn a skill, they show *hyperspecific* memory: They can express this learning only in a context extremely similar to the conditions of encoding. In a sense, this seems to be a version of the encoding specificity principle carried to the extreme.

## Retrograde Amnesia

Loss of memory for information acquired and stored before the onset of amnesia is known as **retrograde amnesia.** Although such loss has some similarities with anterograde amnesia, important differences appear as well. Interestingly, all amnesic patients seem to show at least some retrograde amnesia; they may or may not exhibit anterograde amnesia. Cohen (1997) described four basic features of retrograde amnesia.

The first is that the temporal extent—the time span for which memory is lost—can vary enormously in retrograde amnesia. Patients suffering from Korsakoff's, Alzheimer's, Parkinson's, or Huntington's disease are likely to exhibit temporally extensive amnesia, with loss of memory acquired and stored for several decades. Other patients, such as those who have undergone bilateral ECT or suffered a closed head injury, show temporally limited retrograde amnesia, losing information for a span of only months or perhaps weeks. In many cases, over time the patient either fully (in the case of ECT) or partially recovers the lost memories. Damage to the hippocampal region can also cause retrograde amnesia. H.M.'s retrograde amnesia was found to cover a span of 11 years, less than for some other cases reported in the literature.

A second feature of retrograde amnesia is observable when scientists examine which particular memories are lost. Figure 6-10 plots some relevant data. Patients undergoing ECT treatments were asked to recall information about

**FIGURE 6-9** ■ *(FACING PAGE) An example of a spared perceptual skill in patients with amnesia. (A) Examples of the mirror-image word triads used in a mirror-image reading task (Cohen & Squire, 1980). (B) Just like control individuals, patients who have amnesia from different causes—patient N.A., who has midline diencephalic damage (top); patients with Korsakoff's amnesia (middle); and patients who underwent electroconvulsive therapy (ECT) (bottom)—increased the speed with which they could read the triads. This increase occurred not only for repeated triplets (triplets that they saw before; graphs on the right) but also for new (nonrepeated) triads (graphs on the left). The increase in the reading times for novel triplets indicates that the patients with amnesia were learning the perceptual skill of mirror-image reading.*

**SOURCE:** Cohen (1997, p. 330).

television shows that had aired for a single season only (that way, the experimenters knew precisely when the memories were formed; this study was conducted well before the proliferation of cable channels!). Before the ECT treatments, the patients were best at recalling facts from very recently aired shows, as you would be. After the ECT treatments, however, these same patients' data showed a temporal gradient, with the most recent memories being the most likely to be lost (Cohen, 1997).

In the case of ECT patients, we would expect full recovery, in time, of the lost memories. With patients suffering from a closed head injury, the story is a little different. There, the temporal extent of the retrograde amnesia often shrinks slowly over time, with the most remote memories being the most likely to return. For example, initially the retrograde amnesia might span several years before the head trauma occurred; after a year in recovery, the total span of retrograde amnesia might be the two weeks immediately preceding the trauma.

Cohen (1997) described a third feature of retrograde amnesia: It typically spares information that was "overlearned" before the onset.

> Despite their extensive retrograde amnesias, patients with amnesia associated with Korsakoff's disease, anoxia, or encephalitis have intact knowledge about the world; preserved language, perceptual, and social skills; and spared general intelligence. Only the extensive retrograde amnesias associated with progressive dementias, as in Alzheimer's disease or Huntington's disease, impair this kind of information, and then only later in the progression of the disease. (p. 339)

Finally, as with anterograde amnesia, retrograde amnesia seems not to affect skill learning, such as mirror tracing. Even when patients cannot remember ever having practiced the skill, their performance still seems to show normal rates of improvement (Cohen, 1997).

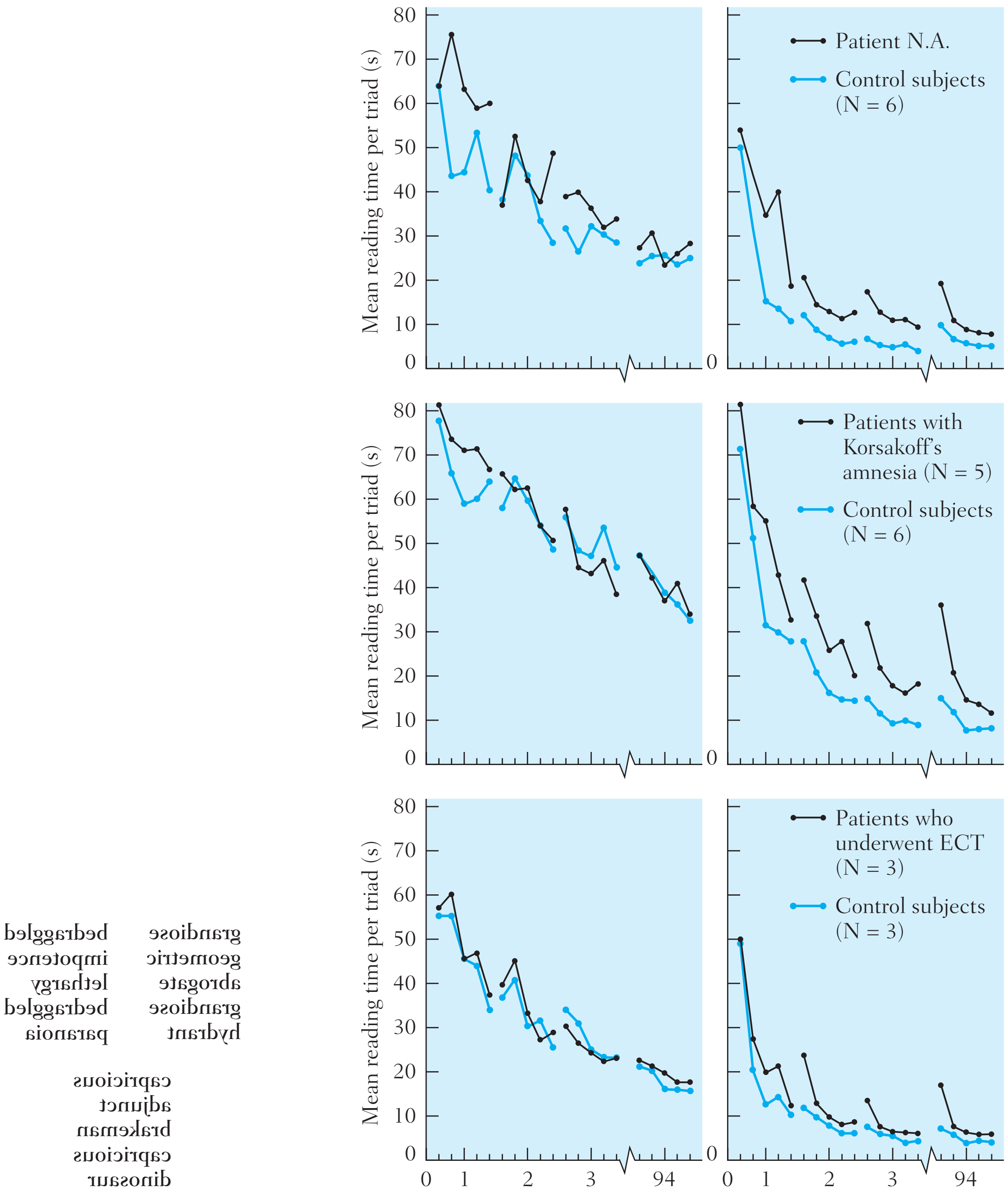
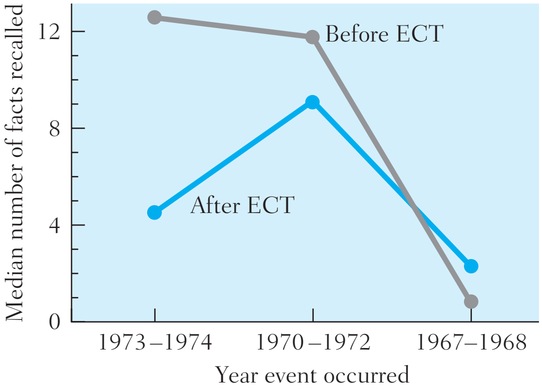

bedraggled
impotence
lethargy
bedraggled
paranoia
grandiose
geometric
abrogate
grandiose
hydrant
capricious
adjunct
brakeman
capricious
dinosaur
(A)
Mean reading time per triad (s)
80
70
60
50
40
30
20
10
0
Patient N.A.
Control subjects (N = 6)
Patients with Korsakoff's amnesia (N = 5)
Control subjects (N = 6)
Patients who underwent ECT (N = 3)
Control subjects (N = 3)
0
1
2
3
94
Day
(B)

**FIGURE 6-10** ■ *Evidence of temporally limited retrograde amnesia in patients who have undergone electroconvulsive therapy (ECT). Before and after a series of ECT treatments, 20 individuals were asked to recall information about former television programs that aired for just one season. Shown here is a graph of the median number of facts recalled. Before ECT, patients showed a normal forgetting curve; their best recall was for shows from the most recent time period, and their poorest recall was for shows from the most remote time period. After ECT, a selective impairment occurred in the recall of shows from the most recent time period.*

**SOURCE:** Cohen and Eichenbaum (1993).



Many neuropsychologists believe the study of amnesia supports some specific ideas about the organization of memory in general. That amnesia can disrupt long-term memory without any impairment in working memory provides some support for considering these as two distinct types of memory. That retrograde amnesia covers a defined time span and shows a temporal gradient implies that even after being formed, new memories continue to undergo neurological change for some period of time, perhaps years. That some kinds of information (personal memories, memories for events or random tidbits of information) are lost in amnesia and others are not (such as overlearned and well-practiced information and skills) has suggested many different kinds of memory systems to some (though not all) psychologists, as we will see in Chapter 7. Finally, there is a strong suggestion that the structure in the brain known as the hippocampus plays a very important role in the retrieval of memories for information, although clearly not all long-term memories require involvement of the hippocampus (otherwise, amnesic patients would never recall any previously learned information).

McGaugh (2000) notes that studies of amnesic patients also tell us something about **memory consolidation,** a process originally proposed a century ago. The idea is that new information "initially persist[s] in a fragile state and consolidate[s] over time" (p. 248). Blows to the head disrupt this process, causing newly learned information to be lost. Some of McGaugh's work suggests an important role for the amygdala, a structure we discussed earlier, in the memory consolidation process.

Throughout this chapter, we've been focusing on memory for specific events (such as hearing a particular word list or witnessing a crime). Often, however, our memories of a particular event call on our memories of general knowledge. For example, if I were to recall the last lecture I gave, I might use my general knowledge about lectures (where students sit or the kinds of equipment, such as chalk or overhead projectors, that I typically use) to reconstruct my memory of that particular class. In the next chapter, we will examine more closely the ways in which this general knowledge is stored and organized.

As stated before, memory touches just about every cognitive activity we can think of. Thus it should come as no surprise that memory bears on many other chapters in this book. In particular, in Chapter 7 we will take up the question of different memory systems, especially as they pertain to our memory for general knowledge. Chapter 8 will continue the discussion of memory for general knowledge as we look specifically at how we form new concepts. In Chapter 9, when we discuss visual imagery, we will come back to issues of how information is encoded and mentally represented. We will see in other chapters that memory plays a significant role in almost every instance of cognitive processing. Thus, as new research on the topic of memory changes our conceptions of how it works, we can expect new developments in almost every other area of cognition.

## SUMMARY

1. We've seen in this chapter, as well as in Chapter 5, that cognitive psychologists approach the study of memory in a variety of ways and that this diversity dates back at least to "founding" cognitive psychologists such as Ebbinghaus and Bartlett. Some of the diversity arises in theoretical orientations: Some psychologists seek evidence for the proposition that there are different memory *stores* (for example, sensory memory, STM, LTM), whereas others focus on the kind of processing done with to-be-remembered information.
2. Within the modal model of memory, LTM is described as the storage of vast amounts of information, usually coded by meaning, for durations ranging up to several decades if not indefinitely.
3. Theories of forgetting from LTM emphasize interference as a very important mechanism. An elaboration of this idea is that when retrieval cues become linked to multiple targets, they become less reliable in the person's ability to pick out a given target.

4. Retrieval of information is made easier when the information to be retrieved is categorized, when the retrieval cues match the cues that were available at the time of encoding (the encoding specificity principle), and when the retrieval cues are very distinctive.
5. Consistent with the encoding specificity principle, investigators have found that recall (but not recognition) is made easier when the recall context is the same as the learning context (the context effect), when the pharmacological state of the person at recall matches his or her pharmacological state during encoding (the state-dependent learning effect), and, under some conditions, when the person's mood at the time of recall matches his or her mood at the time of learning (the mood-dependent memory effect). Recall is also enhanced when material is learned in several temporally spaced sessions as opposed to one long learning session (the spacing effect).
6. Work on the levels-of-processing theory has demonstrated that the more active and meaningful the original processing of information, the more memorable the information will be. This idea has obvious and practical relevance for students: If you want to improve your recall of material for later testing (in midterms and finals), organize it and think about its meaning (deep processing) rather than merely reading, underlining, or highlighting the words (shallow processing).
7. The work reported here on people's recall of their own life events dovetails in several ways with the laboratory-based investigations of memory described in this chapter and the last. Some of the findings that have emerged—for example, the constructive nature of recall—fit well with laboratory findings. However, different results are found in laboratory- and everyday-based studies. Autobiographical recall seems better than recall of laboratory stimuli, but whether different cognitive mechanisms are at work remains an open question.
8. Work on flashbulb and eyewitness memories suggests that people's recollections of moments of their past can be wrong, even when those people seem absolutely convinced of the accuracy of the memory. This suggests that our own confidence in our memories may sometimes be too high; at the very least, there are probably occasions when we are both very sure of our memories and also very wrong. Work on eyewitness testimony suggests that memory traces of a witnessed event are very malleable and subject to disruption by postevent leading questions.
9. Debates over whether memory traces can be repressed for long periods of time, then recalled, have erupted in recent years. Some studies purport to show that under repeated urgings, people can be induced to "recall" emotional events that never happened. One study suggests there may well be limits to the types of "false" memories that can be so implanted, but as yet we do not have a firm understanding of what these limits are.

10. Neuropsychologists who study memory deficits recognize two different kinds of amnesia. Both seem to involve damage to either the hippocampal system or the midline diencephalic region. This damage can arise in several different ways: through closed head injury, a stroke, oxygen deprivation to the brain, bilateral electroconvulsive shock treatments, a virus such as encephalitis, or other diseases such as Alzheimer's or Korsakoff's.
11. Anterograde amnesia, which extends forward in time from the onset of amnesia, selectively affects long-term (but not working) memory, regardless of modality or type of memory test, and spares memory for general knowledge and skilled performance (although the learning of the latter will not be explicitly remembered) but can result in memories for skills that are hyperspecific to the original learning context and cannot be transferred to other, similar contexts.
12. Retrograde amnesia, the loss of memory acquired and stored before the point of onset, is almost always a component of amnesia. The temporal extent of the amnesia varies in different patients; it is worst for memories of information acquired closest to the point of onset. Some recovery of some of the lost retrograde memories is often possible. Retrograde amnesia also spares material that has been "overlearned" before the onset, including such things as language, general knowledge, and perceptual and social skills. As with anterograde amnesia, retrograde amnesia seems to spare skill learning.

## REVIEW QUESTIONS

1. In what ways do the underlying assumptions of the levels-of-processing theory differ from the underlying assumptions of the modal model?
2. Describe the different kinds of interference and how they are theorized to operate.
3. Describe and evaluate encoding specificity as a principle of retrieval of information. How does it relate to such phenomena as the spacing effect, state-dependent learning, and context effects on retrieval?
4. Explore the interrelationships among the context effect, the state-dependent learning effect, the mood-dependent memory effect, and the spacing effect.
5. Apply the cognitive research on memory to the practical problem of giving a college student advice about how to study for an upcoming midterm. What advice would you give, and which principles would this advice draw on?
6. What do the findings of Linton and Brewer suggest about the workings of autobiographic memory for ordinary events?

7. How do findings from the eyewitness testimony and the flashbulb memory literature fit with laboratory-based findings reported earlier? What are the differences, if any?
8. Is there a need to posit special mechanisms for flashbulb memories? Defend your view.
9. Describe the debate over "recovered" versus "false" memories of traumatic events. What are the most important issues for cognitive psychologists to address, and what issues (pragmatic, ethical, theoretical) are they likely to face in doing so?
10. Review the similarities and differences between anterograde and retrograde amnesia.
11. What exactly do findings from memory studies with amnesic patients tell us about the way memory operates in nonamnesic people? (*Note:* This question is a controversial one within the field—can you see why?)

## Key Terms

amnesia
amygdala
anterograde amnesia
autobiographical memory
context effect
cue overload
encoding specificity
encoding variability
eyewitness memory
false memory
fan effect
flashbulb memory
hippocampus
incidental learning
levels-of-processing theory of memory
memory consolidation
mnemonics
mood-dependent memory effect
paired associates learning
recovered memory
repressed memory
retrieval cue
retroactive interference
retrograde amnesia
schemata
spacing effect
state-dependent learning
state-dependent memory

## CogLab Demonstrations

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

Two CogLab demonstrations are relevant to topics discussed in this chapter. The first is **Serial Position,** which provides experience with this phenomenon. In the discussion of false memories, mention was made of the Deese/Roediger–McDermott paradigm, which is shown in the **False Memory** demonstration.

## WEB RESOURCES

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

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PART

# III

# Representation and Organization of Knowledge

7 Memory for General Knowledge
8 Concepts and Categorization
9 Visual Imagery and Spatial Cognition

## CHAPTER 7

# Memory for General Knowledge

**The Semantic/Episodic Distinction**

**Semantic Memory Models**
- The Hierarchical Semantic Network Model
- The Feature Comparison Model
- Other Network Models
- The ACT Models
- Connectionist Models

**Schemata**
- Scripts

**Implicit Versus Explicit Memory**
- The Process Dissociation Framework

As a psychologist, teacher, and amateur dog trainer, I have a great deal of mentally stored knowledge about different topics. I often surprise my students (and sometimes myself) by remembering the approximate title, author, journal, and year of an article that would complement their independent study projects. Less often, when I teach dog obedience classes and am stumped by a dog who just can't seem to learn a simple task, I can call up from memory an idea I heard about years ago at a dog-training seminar. Obviously, when I remember or recall these pieces of information I am using my memory.

How do I hold onto information in such a way that I can access it, sometimes years after I've stored it? Consider the vast range of information everyone must have stored in permanent memory. In addition to information regarding events in your life (your sixth birthday party, the time you broke your arm, going to the circus, your first day of junior high), you have also stored a great deal of knowledge: definitions of the words you know; arithmetic facts and procedures; historical, scientific, and geographic knowledge; and (I hope) even some knowledge of principles of cognitive psychology. In this chapter, we will take a more detailed look at this kind of permanent memory—memory for knowledge and information.

One question that will concern us is how stored knowledge is organized. There are several distinct ways of arranging and storing information, and each has different implications for ease of access and retrieval. An analogy to your bookshelves may help. Think about your books and how they are arranged. You may have a section for textbooks, a section for nonfiction, a section for mysteries, and a section for trashy romances. Or you may have all the books arranged alphabetically by author. Or you may have tall books on one shelf, paperbacks on another. Each possibility represents a different way of organizing.

Each possibility has different implications for how you look for a particular book and how easy it is to find it. Suppose you want to find *Gone with the Wind,* but you've forgotten the author's name. If you've arranged your books alphabetically by author, you'll have a much more difficult time than if you've arranged them by title or by category. A variety of models have been proposed for how our knowledge is mentally represented and organized. Each makes different predictions about how we search for particular pieces of information.

To start, do your memories of specific events (say, your sixth birthday party) differ in important ways from your memories of general knowledge (for example, that 2 + 2 = 4)? Endel Tulving (1972, 1983) drew a distinction between memories for events and memories for general knowledge. He argued that long-term memory consists of two separate and distinct yet interacting systems.

One system, **episodic memory,** holds memories of specific events in which you yourself somehow participated. The other system, **semantic memory,** holds information that has entered your general knowledge base: You can recall parts of that base, but the information recalled is generic—it doesn't have much to do with your personal experience. For example, your memory that Sigmund Freud was a founding practitioner of psychoanalysis is presumably in your general knowledge base but divorced from your personal memories of what happened to you at a certain time. It's probable, actually, that you can't even remember when the fact about Freud entered your memory.

Contrast this situation with when information about your first date or the 9/11 attacks on the World Trade Center and Pentagon entered your memory. For those instances you may recall not only the information itself but also the circumstances surrounding your acquisition of the information (where, when, why, how, and from whom you heard, saw, or otherwise acquired it), as we saw in Chapter 6.

After reviewing arguments and evidence for the episodic/semantic distinction, we'll go on to concentrate on semantic memory. Specifically, we'll look at a number of proposals for how our knowledge base or bases are organized and the implications that organization has for the ways we access information.

Finally, we'll review some work suggesting that some of our memories are not accessible to our conscious recollection. Some psychologists use the term *implicit memory* to describe phenomena in which some experiences leave memory traces without our being aware of them; we know these traces exist, however, when they are shown to influence our behavior later. Work with amnesic patients will be relevant to our understanding here once again. We will see that much of the work on implicit memory is carried out within a semantic memory framework.

## THE SEMANTIC/EPISODIC DISTINCTION

Tulving (1972, 1983, 1989) proposed a classification of long-term memories into two kinds: episodic and semantic. Episodic memory is memory for information about one's personal experiences. As Tulving (1989) put it, episodic memory "enables people to travel back in time, as it were, into their personal past, and to become consciously aware of having witnessed or participated in events and happenings at earlier times" (p. 362). Episodic memory has also been described as containing memories that are temporally dated; the information stored has some sort of marker for when it was originally encountered.

Any of your memories that you can trace to a single time are considered to be in episodic memory. If you recall your high school graduation, or your first meeting with your first-year roommate, or the time you first learned of an important event, you are recalling episodic memories. Even if you don't recall the exact date or even the year, you know the information was first presented at a particular time and place, and you have a memory of that presentation.

Semantic memory, in contrast, is thought to store general information about language and world knowledge. When you recall arithmetic facts (for example, "2 + 2 = 4"), historical dates ("In fourteen hundred and ninety-two, / Columbus sailed the ocean blue"), or the past tense forms of various verbs *(run, ran; walk, walked; am, was),* you are calling on semantic memory.

Notice in these examples that in recalling "2 + 2 = 4," you aren't tracing back to a particular moment when you learned the fact, as you might do with the 9/11 attacks. Instead of "remembering" that 2 + 2 = 4, most people speak of "knowing" that 2 + 2 = 4. This distinction between memories of specific moments and recall from general knowledge marks the major difference between semantic and episodic memory. Why make such a distinction? Doing so captures our intuition that the recall of some things differs from the recall of others. Recalling your graduation simply has a different "feel" from recalling the sum of 2 and 2.

Tulving (1972, 1983, 1989) described episodic and semantic memory as **memory systems** that operate on different principles and hold onto different kinds of information. Tulving (1983) pointed to a number of differences in the ways episodic and semantic memory seem to work, and I'll describe a few of the major differences here.

As we have just discovered, the nature of the information thought to be held in the two memory systems is different. In episodic memory, we hold onto information about events and episodes that have happened to us directly. In semantic memory, we store knowledge: facts, concepts, and ideas. With episodic memory, the memories are encoded in terms of personal experience. Recalling memories from the episodic system takes the form of "Remember when . . . ." With semantic memory, the information is encoded as general knowledge, context effects are less pronounced, and retrieval of information consists of answering questions from our general knowledge base in the form of "Remember what . . . ." Organization of episodic memory is temporal; that is, one event will be recorded as having occurred before, after, or at the same time as another. Organization of semantic memory is arranged more on the basis of meanings and meaning relationships among different pieces of information.

Schacter (1996) offered a number of case studies of people suffering from different kinds of amnesia that support the episodic/semantic distinction. Gene, for example, survived a motorcycle accident in 1981 (when he was 30 years old) that seriously damaged his frontal and temporal lobes, including the left hippocampus. Gene shows anterograde amnesia and retrograde amnesia. In particular, Gene cannot recall *any* specific past events, even with extensive, detailed cues. That is, Gene cannot recall any birthday parties, school days, or conversations. Schacter noted further that "even when detailed descriptions of dramatic events in his life are given to him—the tragic drowning of his brother, the derailment near his house, of a train carrying lethal chemicals that required 240,000 people to evacuate their homes for a week—Gene does not generate any episodic memories" (p. 149).

In contrast, Gene recalls many facts (as opposed to episodes) about his past life. He knows where he went to school; he knows where he worked. He can name former coworkers; he can define technical terms he used at the manufacturing plant where he worked before the accident. Gene's memories, Schacter argued, are akin to the knowledge we have of other people's lives. You may know, for example, about incidents in your mother's or father's lives that occurred before your birth: where they met, perhaps, or some memorable childhood incidents. You know *about* these events, although you do not have specific *recall* of them. Similarly, according to Schacter, Gene has *knowledge* of some aspects of his past (semantic memory), but no evidence of any *recall* of specific happenings (episodic memory).

Schacter (1996) also described neuropsychological case studies of people with deficits that are "mirror images" of Gene's. A case was reported, for instance, of a woman who, after a bout of encephalitis and resultant damage to the front temporal lobe,

> no longer knew the meanings of common words, had forgotten virtually everything she once knew about historical events and famous people, and retained little knowledge of the basic attributes of animate and inanimate objects. She had difficulty indicating the color of a mouse, and had no idea where soap would ordinarily be found. . . . However, when asked about her wedding and honeymoon, her father's illness and death, or other specific past episodes, she readily produced detailed and accurate recollections. (p. 152)

These two cases, and others like them (some described by Schacter, 1996; see also Riby, Perfect, & Stollery, 2004), provide some clinical neuropsychological evidence supporting the idea that episodic memory and semantic memory operate independently. That is, the existence of people in whom one type of memory seems seriously impaired while the other appears spared gives concrete evidence for the existence of two separate systems of memory.

Tulving (1989) also reported some cases in which the cerebral blood flow patterns were different when volunteer participants were asked to lie quietly and retrieve either an episodic or a semantic memory. Episodic retrieval tended to be associated with more frontal lobe activity than did semantic memory. Unfortunately, not all participants showed these effects; some showed no discernible differences, making any straightforward interpretation of these results impossible as of yet. Other work has suggested that different neural areas are activated during episodic versus semantic memory retrieval, although the patterns of neural activity underlying different kinds of memory retrieval share similarities and are not completely distinct (Menon, Boyett-Anderson, Schatzberg, & Reiss, 2002; Nyberg, Forkstam, Petersson, Cabeza, & Ingvar, 2002). A recent study suggests that atrophy of the perirhinal cortex in the temporal lobe and directly connected areas affects semantic but not episodic memory (Davies, Graham, Xuereb, Williams, & Hodges, 2004).

Tulving's (1972, 1983, 1989) proposals have provoked strong controversy within the field of cognitive psychology. McKoon, Ratcliff, and Dell (1986) presented a series of arguments centering on the usefulness of considering episodic and semantic memories to be two separate memory *systems* and on the kind of evidence needed to support the distinction. Many psychologists find it hard to draw sharp lines between knowledge that includes information about the time it was first learned and knowledge that is more "generic" in character (Baddeley, 1984). However, almost everyone agrees that at the very least there seem to be two kinds of memories—semantic and episodic—even if they are stored within a single system. Most of the topics covered in Chapters 5 and 6 had to do with episodic memory. After all, when participants in an experiment are given a list of words to remember, they are later asked to recall *those* words, which they memorized at a particular time, not just any words they happen to know. In the rest of this chapter, we will concentrate on semantic memory, considering the way general knowledge is stored, processed, and retrieved.

Semantic memory is thought to have enormous capacity; hence, it is important to know how such memory is organized. We've already discussed the library analogy for semantic memory. This metaphor grows out of an information-processing paradigm, which sees memory as consisting of one or more distinct storage areas. If a library (storage area) contains only a handful of books, it makes little difference how they are arranged or stored; it would be an easy matter for a patron looking for a particular book simply to browse through the entire collection. As the number of books grows, however, the need for some sort of organizational system becomes pressing. One might say knowledge bases are comparable to a large library; therefore, understanding their organization is crucial for understanding how we retrieve and use information. Later we will see that connectionist models view the organization of knowledge very differently, and reject this library metaphor.

## SEMANTIC MEMORY MODELS

Many of the semantic memory models developed because psychologists and computer scientists interested in the field of artificial intelligence wanted to build a system having what most people refer to as "commonsense knowledge." The premise was that associated with your knowledge of an explicit fact is a great deal of implicit knowledge, information you know but take for granted.

Here's an example of implicit knowledge in our understanding of everyday routines. Consider the typical directions on a shampoo bottle: "Wet hair. Apply shampoo. Lather. Rinse. Repeat." If you slavishly followed these directions, you would emerge from the shower only when the bottle was empty! However, most of us do manage a shampoo, even before our first cup of coffee. What we rely on is not just the directions but our world knowledge or common sense that one or two repetitions of the lather–rinse cycle are sufficient (Galotti & Ganong, 1985).

Our vast knowledge of language and concepts also appears to have associated with it a great deal of implicit knowledge. For instance, if I asked you, "Does a Bernese mountain dog have a liver?" you would very likely answer yes (correctly). Your answer comes (I assume) not from your extensive study of Bernese mountain dogs but from your knowledge that Bernese mountain dogs are dogs, dogs are mammals, mammals have livers. In this section, we will consider models of how knowledge is represented in semantic memory such that we can make these inferences and demonstrate our common sense.

To build such models, we need to make a number of inferences about our mental representations of information from our performance on specific tasks. For example, if we can retrieve some information very quickly (say, think of words beginning with the letter *L*) relative to other information (say, think of words with *L* as the fourth letter), that suggests something about the organization of knowledge. In this example, for instance, we can infer that our **lexicons,** or mental dictionaries, are organized by the first letter, not the fourth, in a word. In the specific models presented next, you'll see that the tasks invented were meant to answer very specific questions about the nature of the mental organization of information.

Many of the models described in this chapter were developed in the 1970s, when information-processing analogies between humans and computers were dominating the field of cognitive psychology. We will review some of these "classic" models first, before turning our attention to connectionist models that make quite different assumptions about the representation and organization of knowledge.

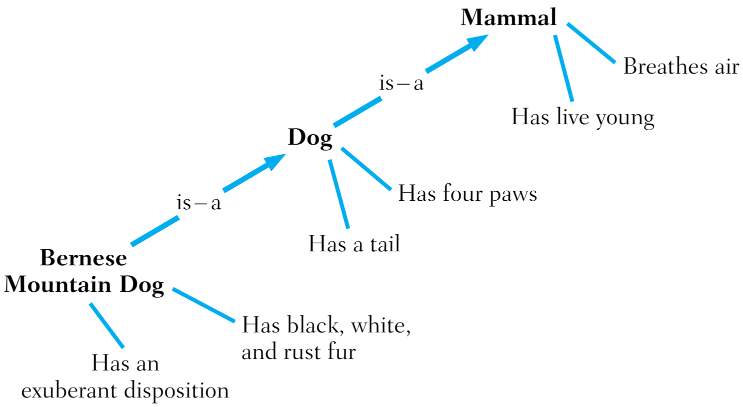
## The Hierarchical Semantic Network Model

Because our world and language knowledge is so great, the storage space requirements to represent it are large. Computer scientists trying to create databases of knowledge decades ago were quite constrained by the very limited memory available to computers of that day, so the models of semantic memory may well have been shaped by this constraint.

One way to conserve memory space would be to try to avoid storing redundant information wherever possible. Therefore, rather than storing the information "has live young" with the mental representation for Bernese mountain dog and again with the mental representations for human, lion, tiger, and bear, it makes more sense to store it once, at the higher-level representation for mammal. This illustrates the principle of **cognitive economy:** Properties and facts are stored at the highest level possible. To recover information, you use inference, much as you did to answer the earlier question about Bernese mountain dogs' having livers.

A landmark study on semantic memory was performed by Collins and Quillian (1969). They tested the idea that semantic memory is analogous to a network of connected ideas. As in later connectionist networks, this one consists of nodes, which in this case correspond roughly to words or concepts. Each node is connected to related nodes by means of *pointers,* or links that go from one node to another. Thus the node that corresponds to a given word or concept, together with the pointers to other nodes to which the first node is connected, constitutes the semantic memory for that word or concept. The collection of nodes associated with all the words and concepts one knows about is called a **semantic network.** Figure 7-1 depicts a portion of such a network for a person (such as me) who knows a good deal about Bernese mountain dogs. Readers familiar with computer science may be reminded of linked lists and pointers, a metaphor that Collins and Quillian intended.

**FIGURE 7-1** ■ *Partial semantic network representation for Bernese mountain dog.*



Collins and Quillian (1969) also tested the principle of cognitive economy, just described. They reasoned that if semantic memory is analogous to a network of nodes and pointers and if semantic memory honors the cognitive economy principle, then the closer a fact or property is stored to a particular node, the less time it should take to verify the fact and property. Collins and Quillian's reasoning led to the following prediction: If a person's knowledge of Bernese mountain dogs is organized along the lines of Figure 7-1, he or she should be able to verify the sentence "A Bernese mountain dog has an exuberant disposition" more quickly than to verify "A Bernese mountain dog has live young." Note that the property "has an exuberant disposition" is stored right with the node for Bernese mountain dog, indicating that this property is specific to this kind of animal. The property "has live young" is not specific to Bernese mountain dogs, so it is stored a number of levels higher in the hierarchy.

In their study (see Figure 7-2), Collins and Quillian (1969) presented people with a number of similar sentences, finding, as predicted, that it took people less time to respond to sentences whose representations should span two levels (for example, "A canary is a bird") than they did to sentences whose representations should span three (for example, "A canary is an animal").

Image not available due to copyright restrictions

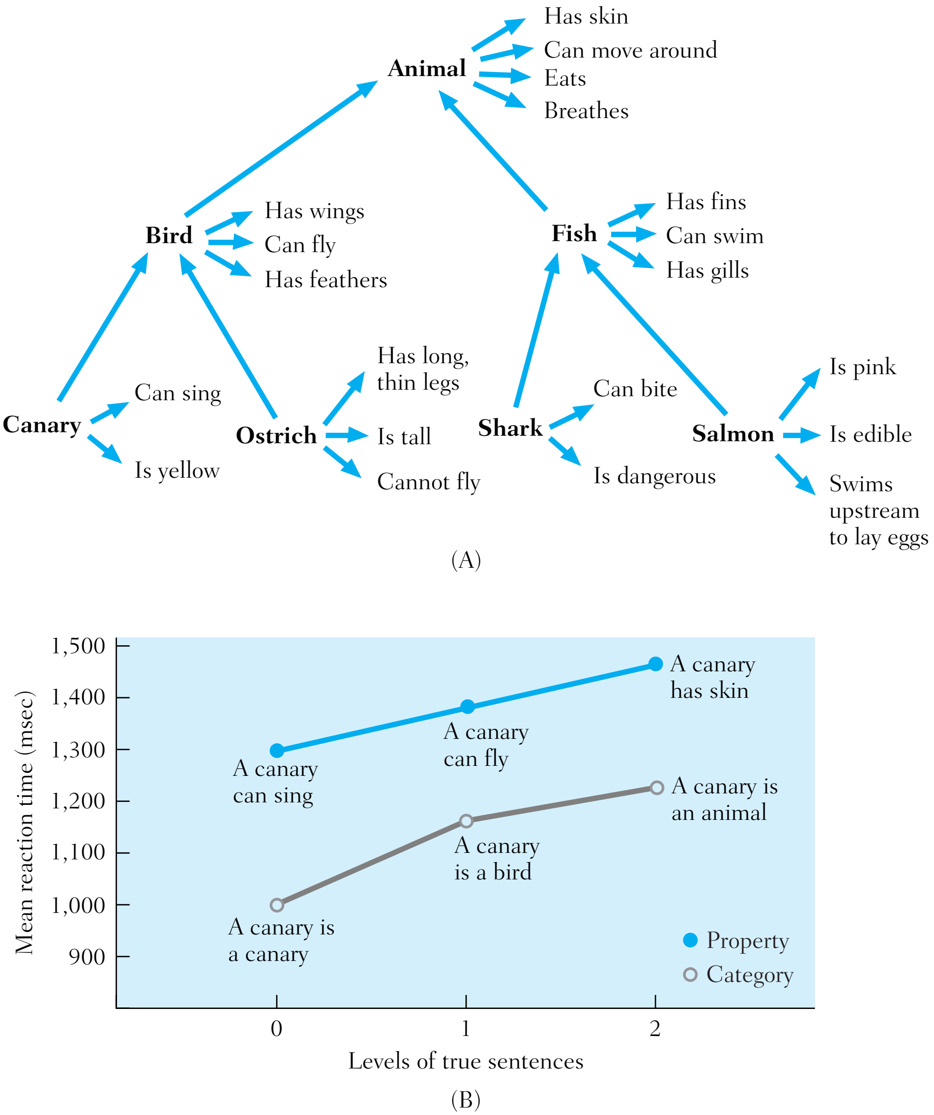
The model was called a **hierarchical semantic network model of semantic memory,** because researchers thought the nodes were organized in hierarchies. Most nodes in the network have superordinate and subordinate nodes. A superordinate node corresponds to the name of the category of which the thing corresponding to the subordinate node is a member. So, for example, a node for "cat" would have the superordinate node of "animal" and perhaps several subordinate nodes, such as "Persian," "tabby," and "calico."

Meyer and Schvaneveldt (1971) performed a series of experiments that elaborated the semantic network proposal. They reasoned that if related words are stored close by one another and are connected to one another in a semantic network, then whenever one node is activated or energized, energy spreads to the related nodes, as in Figure 7-3. They demonstrated this relationship in a series of experiments based on **lexical decision tasks.** In this kind of experiment, participants see a series of letter strings and are asked to decide, as quickly as possible, if the letter strings form real words. Thus they respond yes to strings such as *bread* and no to strings such as *rencle*.

Meyer and Schvaneveldt (1971) discovered an interesting phenomenon. In their study, participants saw two words at a time, one above the other, and had to decide if both strings were words or not. If one of the strings was a real word (such as *bread*), participants were faster to respond if the other string was a semantically associated word (such as *butter*) than if it was an unrelated

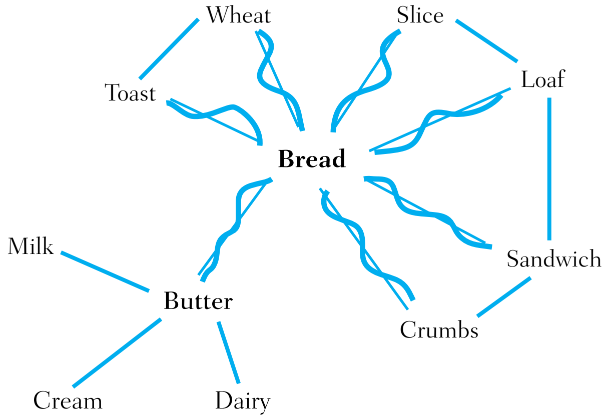
**FIGURE 7-2** ■ *Illustration of the Collins and Quillian (1969) experiment. Panel A shows the hypothesized underlying semantic network, and Panel B shows reaction times to verify sentences about information in the semantic network.*

**SOURCE:** Collins and Quillian (1969, p. 241).


Animal
Has skin
Can move around
Eats
Breathes
Bird
Has wings
Can fly
Has feathers
Fish
Has fins
Can swim
Has gills
Canary
Can sing
Is yellow
Ostrich
Has long, thin legs
Is tall
Cannot fly
Shark
Can bite
Is dangerous
Salmon
Is pink
Is edible
Swims upstream to lay eggs
(A)
Mean reaction time (msec)
1,500
1,400
1,300
1,200
1,100
1,000
900
A canary has skin
A canary can fly
A canary can sing
A canary is an animal
A canary is a bird
A canary is a canary
● Property
○ Category
0
1
2
Levels of true sentences
(B)

word (such as *chair*) or a nonword (such as *rencle*). One interpretation of this finding invokes the concept of **spreading activation,** the idea that excitation spreads along the connections of nodes in a semantic network. Presumably, when the person read the word *bread,* he activated the corresponding node in

**FIGURE 7-3** ■ *Depiction of spreading activation. Once the node for "bread" is excited, the activation travels to related nodes.*



semantic memory. This activity primed, or changed the activation level of, the nodes corresponding to words related to *bread*. Thus, when processing of the word *butter* began, the node corresponding to it was already excited, and processing was consequently faster. This priming effect, originally discovered by Meyer and Schvaneveldt, has been widely replicated in the years since (see Neely, 1990), and is a very important idea in understanding connectionist networks, to be described later.

You may note here a connection to the research on the word superiority effect described in Chapter 3. Recall that people are generally faster to recognize a particular letter (such as *D* or *K*) in the context of a word (such as *WOR_*) than they are to recognize it with no context or in the context of a nonword (such as *OWR_*). The explanations offered went roughly along the following lines: The word context helps letter recognition because a node corresponding to a word is activated in the former case. This automatic activation facilitates recognition of all parts of the word, thus facilitating letter recognition. The Meyer and Schvaneveldt (1971) results extend this idea a little more: Individual nodes can be activated not just directly, from external stimuli, but indirectly, through spreading activation from related nodes.

Soon after Collins and Quillian (1969) presented their model, others found evidence that contradicted the model's predictions. One line of evidence was related to the prediction of cognitive economy, the principle that properties and facts would be stored with the highest and most general node possible.

Carol Conrad (1972) found evidence to contradict this assumption. Participants in her sentence verification experiments were no slower to respond to sentences such as "A shark can move" than to "A fish can move" or "An animal can move." However, the principle of cognitive economy would predict that the property "can move" would be stored closest to the node for "animal" and thus that the three sentences would require decreasing amounts of time to verify. Conrad argued that the property "can move" is one frequently associated with "animal," "shark," and "fish" and that frequency of association rather than cognitive economy predicts reaction time.

A second prediction of Collins and Quillian's (1969) model had to do with hierarchical structure. Presumably, if the network represents such words (that in turn represent concepts) as *animals, mammals,* and *pigs,* then it should do so by storing the node for "mammal" under the node for "animal," and the node for "pig" under the node for "mammal." However, Rips, Shoben, and Smith (1973) showed that participants were faster to verify "A pig is an animal" than to verify "A pig is a mammal," thus demonstrating a violation of predicted hierarchical structure.

A third problem for the hierarchical network model was that it failed to explain why certain other findings kept appearing. One such finding is called a **typicality effect.** Rips et al. (1973) found that responses to sentences such as "A robin is a bird" were faster than responses to "A turkey is a bird," even though these sentences should have taken an equivalent amount of time to verify. In general, typical instances of a concept are responded to more quickly than atypical instances; robins are typical birds, and turkeys are not. The hierarchical network model did not predict typicality effects; instead, it predicted that all instances of a concept should be processed similarly.

These, among other problems, led to some reformulations as well as to other proposals regarding the structure of semantic memory. Some investigators abandoned the idea of networks altogether; others tried to extend and revise them. We'll consider each of these approaches in turn.

## The Feature Comparison Model

Smith, Shoben, and Rips (1974) proposed one alternative to the hierarchical semantic network model, called a **feature comparison model of semantic memory.** The assumption behind this model is that the meaning of any word or concept consists of a set of elements called *features.* (We encountered the idea of features earlier, in Chapter 3, when we reviewed models of perception.) **Features** come in two types: **defining,** meaning that the feature must be present in every example of the concept, and **characteristic,** meaning the feature is usually, but not necessarily, present.

For instance, think about the concept "bachelor." The defining features here include "male," "unmarried," and "adult." It is not possible for a 2-year-old to be a bachelor (in our common use of the term), nor for a woman, nor for a married man. Features such as "is young" or "lives in own apartment" are also typically associated with bachelors, though not necessarily in the way that "male" and "unmarried" are—these are the characteristic features. Table 7-1 lists features for three concepts.

**Table 7-1** Lists of Features for Three Concepts

| *Bachelor* | *Bernese Mountain Dog* | *Chair* |
|---|---|---|
| Male | Dog | Furniture |
| Adult | Black, white, and rust fur | Has a seat |
| Unmarried | Brown eyes | Has a back |
| Human | Large size | Has legs |
| | Bred for draft | |

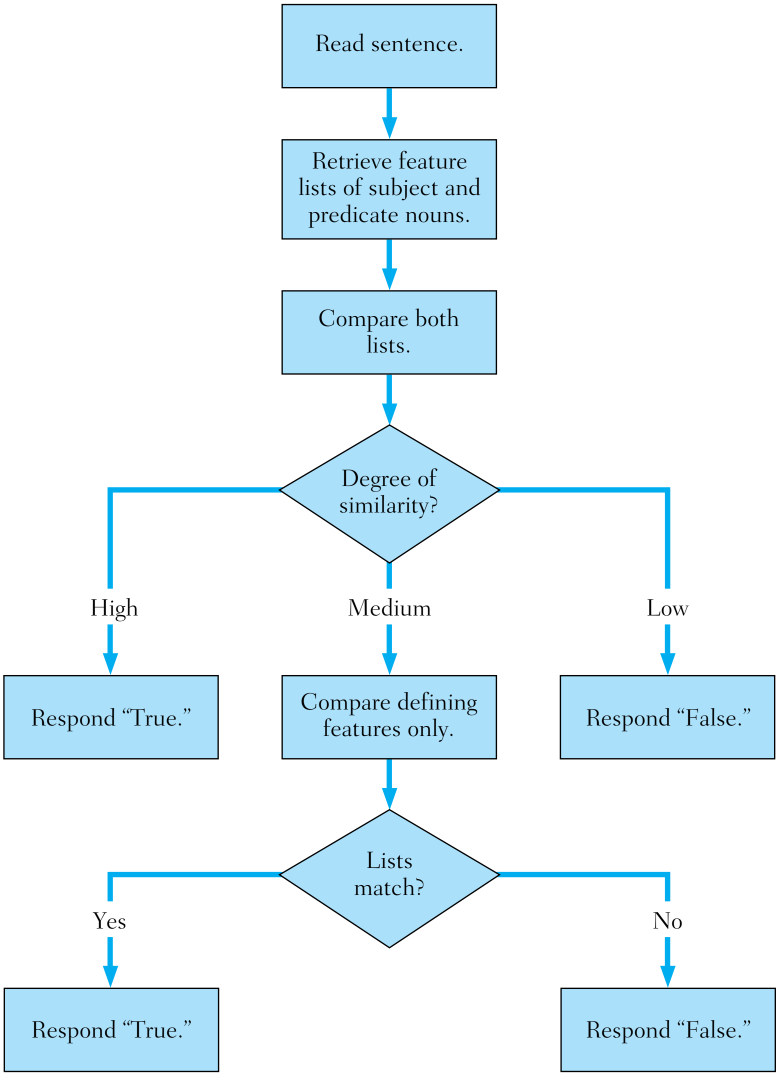
Assuming that semantic memory is organized in terms of feature lists, how is its knowledge retrieved and used? In particular, how can performance on a sentence verification task be explained? In the Smith et al. (1974) model, the verification of sentences such as "A robin is a bird" is again carried out in two stages, as in Figure 7-4. In the first stage, the feature lists (containing both the defining and the characteristic features) for the two terms are accessed, and a quick scan and comparison are performed. If the two lists show a great deal of overlap, the response "true" is made very quickly. If the overlap is very small, then the response "false" is made, also very quickly. If the degree of overlap in the two feature lists is neither extremely high nor extremely low, then a second stage of processing occurs. In this stage, a comparison is made between the sets of defining features only. If the lists match, the person responds "true"; if the lists do not match, the person responds "false."

The feature comparison model can explain many findings that the hierarchical network model could not. One finding it explains is the typicality effect: Sentences such as "A robin is a bird" are verified more quickly than sentences such as "A turkey is a bird" because robins, being more typical examples of birds, are thought to share more characteristic features with "bird" than do turkeys. The feature comparison model also explains fast rejections of false sentences, such as "A table is a fruit." In this case, the list of features for "table" and the list for "fruit" presumably share very few entries.

The feature comparison model also provides an explanation for a finding known as the *category size effect* (Landauer & Meyer, 1972). This term refers to the fact that if one term is a subcategory of another term, people will generally

**FIGURE 7-4** ■ *Depiction of the Smith et al. (1974) feature comparison model.*

**SOURCE:** Smith et al. (1974, p. 22).


Read sentence.
Retrieve feature lists of subject and predicate nouns.
Compare both lists.
Degree of similarity?
High
Medium
Low
Respond "True."
Compare defining features only.
Respond "False."
Lists match?
Yes
No
Respond "True."
Respond "False."

be faster to verify the sentence with the smaller category. That is, people are faster to verify the sentence "A collie is a dog" than to verify "A collie is an animal," because the set of dogs is part of the set of animals. The feature comparison model explains this effect as follows. It assumes that as categories grow larger (for example, from robin, to bird, to animal, to living thing), they also become more abstract. With increased abstractness, there are fewer defining features. Thus in the first stage of processing there is less overlap between the feature list of a term and the feature list of an abstract category.

The model can also explain how "hedges" such as "A bat is sort of like a bird" are processed. Most of us know that even though bats fly and eat insects, they are really mammals. The feature comparison model explains that the processing of hedges consists of a comparison of the characteristic features but not the defining features. Because bats share some characteristic features with birds (namely, flying and eating insects), we agree they are "sort of like" birds. We recognize, however, that bats aren't really birds—presumably because they don't share the same defining features.

Despite the successes of the feature comparison model, evidence and arguments began to mount against its being taken as a complete model of how knowledge is represented. Among the most fundamental criticisms is one that rejects the very existence of defining features. Consider a concept such as "bird." Most people would initially agree that "has wings" is a defining feature. But suppose that through genetic or environmental accident a bird's wings are removed. Is it no longer a bird? Other arguments challenge the view that all, or even some, concepts have defining features (Rosch & Mervis, 1975). We will look at these assertions more carefully in Chapter 8 when we examine concepts in more detail.

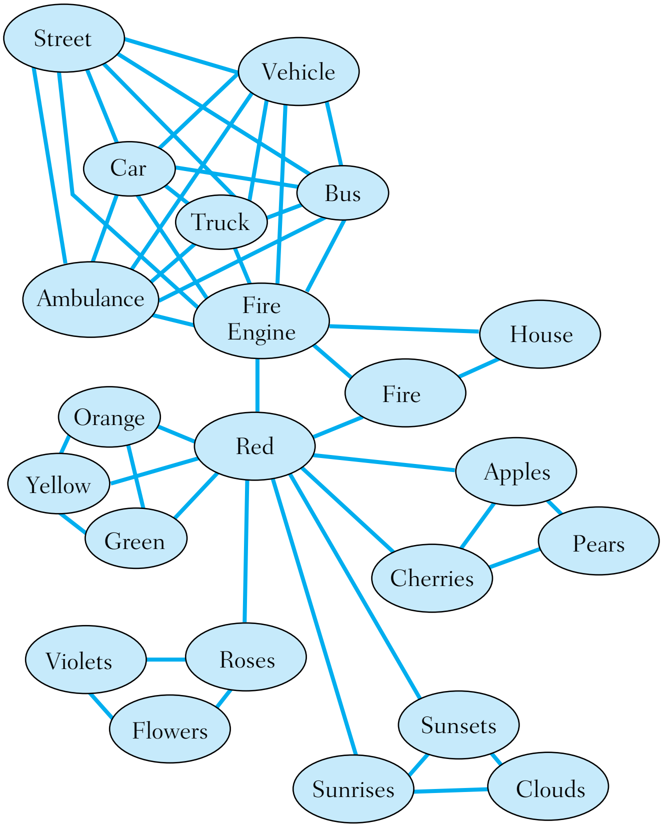
## Other Network Models

Collins and Loftus (1975) presented an elaboration of the Collins and Quillian (1969) hierarchical network model that they called *spreading activation theory.* In general, these authors sought both to clarify and to extend the assumptions made about the manner in which people process semantic information. They again conceived of semantic memory as a network, with nodes in the network corresponding to concepts. They also saw related concepts as connected by paths in the network. They further asserted that when one node is activated, the excitation of that node spreads down the paths or links to related nodes. They believed that as activation spreads outward, it decreases in strength, activating very related concepts a great deal but activating distantly related nodes only a little bit.

Figure 7-5 shows a representation of part of a semantic network, as Collins and Loftus (1975) conceived it. Notice that in this model, very similar concepts—such as "car" and "truck"—have many connecting links and are placed close to each other. Less similar concepts, such as "house" and "sunset" (both are red, at least sometimes), have no direct connections and are therefore spaced far apart. Each link or connection between two concepts is thought to have a certain weight or set of weights associated with it. The weights indicate how important one concept is to the meaning of a concept to which it is

**FIGURE 7-5** ■ *Partial network representation of related concepts. Length of line segments indicates the degree of relatedness or connection between two concepts.*

**SOURCE:** Collins and Loftus (1975, p. 412).


Street
Vehicle
Car
Bus
Truck
Ambulance
Fire Engine
House
Fire
Orange
Red
Yellow
Apples
Green
Pears
Cherries
Violets
Roses
Flowers
Sunsets
Sunrises
Clouds

connected. Weights may vary for different directions along these connections. Thus it may be very important to the meaning of *truck* that it is a type of vehicle, but not so very important to the meaning of *vehicle* that *truck* is an example.

Collins and Loftus (1975) described a number of other assumptions this model makes, together with explanations of how the model accounts for data from many other experiments. They dispensed with the assumptions of cognitive economy and hierarchical organization, helping their model avoid the problems of the Collins and Quillian (1969) model. However, many psychologists find the breadth of this model, which is its major strength, to be its major shortcoming as well, because it is difficult to make clear and strong predictions from the model regarding empirical findings. Thus, although the model is consistent with a number of findings, such as the typicality effect and the category size effect, it is hard to think of data that would falsify the model. The proposal is therefore regarded more as a descriptive framework than as a specific model.

## The ACT Models

Another network theory of memory has been developed and refined over several years by John Anderson (1976, 1983, 1993, 2005; Anderson, Budiu, & Reder, 2001). Called the **adaptive control of thought (ACT) model of memory,** it has evolved over the almost 30 years of its existence, and various versions (ACT-*, ACT-R) exist. Based on analogies to computers, ACT has given rise to several computer simulations of cognitive processing of different tasks. ACT models do not make the semantic/episodic distinction described earlier, but distinguish among three kinds of memory systems. The first is *working memory,* thought to contain information the system is currently using. The other two kinds are **declarative memory** and **procedural memory.**

Declarative memory contains knowledge, facts, information, ideas—basically, anything that can be recalled and described in words, pictures, or symbols. In contrast, procedural memory holds information concerning action and sequences of actions. Su, Merrill, and Peterson (2001) describe the distinction between the two somewhat differently, with declarative memory being explicitly represented and consciously accessible, whereas procedural memory is implicitly represented and thus perhaps not consciously accessible.

For example, when you ride a bicycle, swim, or swing a golf club, you are thought to be drawing on your procedural memory. Here's another example of procedural memory. Right now, almost all the telephones I use have touch-tone pads for dialing. I "know" many phone numbers only by the sequence of moves I make to enter the number on the keypad. If someone asks me for one of these phone numbers (a task that requires me to state information in words), I often find myself at a loss; then I start "dialing" on an imaginary keypad, watching where my finger goes and "reading off" the phone number based on the motions of my finger. You could say my knowledge of the phone number is procedural, not declarative. At least at first, I can't easily put that knowledge into words but can only perform it. Other examples of procedural memory might be your knowledge of how to tie a shoe, ride a bike, play a guitar chord, shift gears in a car. The distinction between declarative and procedural memory should help explain the intuition that your memory of who is currently president of the United States has a qualitatively different feel from your memory of how to execute a particular dance step.

Anderson (1983) believed that declarative memory stores information in networks that contain nodes. There are different types of nodes, including those corresponding to spatial images or to abstract propositions. As with other network models, ACT models allow both for activation of any node and for spreading activation to connected nodes. Anderson also posited the existence of a procedural memory. This memory store represents information in **production rules.** Production rules specify a *goal* to achieve, one or more *conditions* that must be true for the rule to apply, and one or more *actions* that result from applying the rule.

For example, a typical college student could use this production rule: "*If* the goal is to study actively and attentively (goal) *and* the noise level in the dormitory is high (condition) *and* the campus library is open (condition), *then* gather your study materials (action) *and* take them to the library (action) *and* work there (action)." Okay, that example was a bit contrived. But psychologists, computer scientists, and others have used production rules to build computer programs that simulate human problem solving. Box 7-1, from Anderson (1995), presents some examples of production rules for multicolumn subtraction.

## Box 7-1 Production Rules for Multicolumn Subtraction

*If* the goal is to solve a subtraction problem,
*Then* make the subgoal to process the rightmost column.

*If* there is an answer in the current column
and there is a column to the left,
*Then* make the subgoal to process the column to the left.

*If* the goal is to process a column
and there is no bottom digit,
*Then* write the top digit as the answer.

*If* the goal is to process a column
and the top digit is not smaller than the bottom digit,
*Then* write the difference between the digits as the answer.

*If* the goal is to process a column
and the top digit is smaller than the bottom digit,
*Then* add 10 to the top digit
and set as a subgoal to borrow from the column to the left.

*If* the goal is to borrow from a column
and the top digit in that column is not zero,
*Then* decrement the digit by 1.

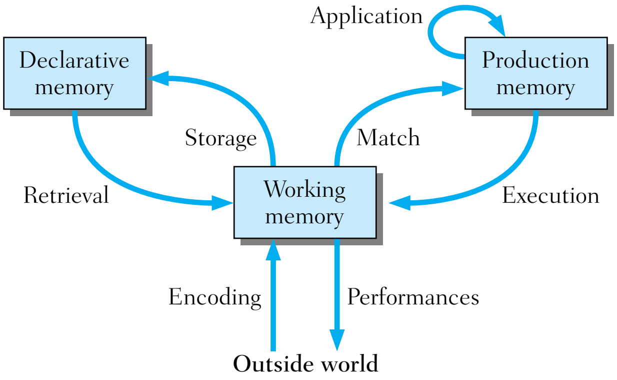
*If* the goal is to borrow from a column
and the top digit in that column is zero,
*Then* replace the zero by 9
and set as a subgoal to borrow from the column to the left.

**SOURCE**: Anderson (1995, p. 282).

Anderson's (1983) proposal was not meant merely to address the question of knowledge representation. Instead, his aim was to create a theory of *cognitive architecture,* a "theory of the basic principles of operation" built into human cognition. He proposed a system that included both memory storage and particular processing structures, as shown in Figure 7-6. Interestingly, this broad goal led him to develop proposals about knowledge representation that fit well with those of researchers whose aims were more focused.

**FIGURE 7-6** ■ *The ACT* cognitive architecture. Adapted from Anderson (1983).*

**SOURCE:** Luger (1994, p. 323).



In the ACT models, working memory is actually that part of declarative memory that is very highly activated at any particular moment. The production rules also become activated when the nodes in the declarative memory that correspond to the conditions of the relevant production rules are activated. When production rules are executed, they can create new nodes within declarative memory. Thus ACT models have been described as very "activation-based" models of human cognition (Luger, 1994).

## Connectionist Models

Earlier in the chapter I referred to the library metaphor, acting as if each piece of information stored in long-term memory existed as a particular item, stored in a particular location, much like a book in a library. This metaphor is a useful one within the information-processing framework, which assumes the existence of one or more distinct "stores" of memory.

Connectionist models make very different assumptions, and thus do not incorporate the library metaphor as easily. Let's take a brief look at connectionist models of memory to try to understand why. James McClelland, a pioneer of connectionist models of cognition, argues that connections models of memory

> [let] go of the idea that items are stored in memory as such. Instead the fundamental idea is that what is stored in memory is a set of changes in the instructions neurons send to each other, affecting what pattern of activity can be constructed from given inputs. When an event is experienced, on this view, it creates a pattern of activity over a set of processing units. This pattern of activity is considered to be the representation of the event. The formation of this pattern of activity provides the trigger for the creation of the instructions. The set of instructions is then stored in the connections among the units, where it is available for use in the construction of subsequent patterns of activity. Under some circumstances—for example, when the constructive process takes place in response to a recall cue—the cue may result in the construction of a pattern of activation that can be viewed as an attempted reconstruction of the pattern that represented the previously experienced event. Such a reconstructed representation corresponds to a recollection. The patterns themselves are not stored, and hence are not really "retrieved"; recall amounts not to retrieval but to reconstruction." (McClelland, 2000, p. 583)

Let's look at a concrete example, comparing network and connectionist models of semantic memory. Figure 7-7(A) presents a semantic network model of various concepts and should look rather familiar. Figure 7-7(B) presents a connectionist model of these same concepts. The concept *robin*, depicted in Figure 7-7(A) as a particular node with several related links to other nodes, is depicted in Figure 7-7(B) as a specific set of units being activated. A unit might correspond to an ability possessed by certain living creatures (e.g., fly) or to certain aspects such as color. Darkened units are activated units, and a connectionist network learns, over trials, that when the unit for "robin" becomes active, then other units should become active as well (for example, "can" and "grow," "move," and "fly," but not "swim").

How does this learning occur? Essentially, a connectionist network must be taught to develop patterns of activation through many trials with training examples. The procedure used, called "back propagation," is actually quite complicated, but I will offer a very simplified version here.

Initially, the connections between units (depicted in Figure 7-7(B) as the lines between the units) have weights that are all set at random and neutral values (such as 0.5, if the minimum and maximum values are 0 and 1). Activation weights result in the units they connect becoming active (or not). Training occurs by presenting a specific example (input pattern) to the network, which then generates a particular output. So, for example, at the beginning of training, the example "robin" might be activated, and the units for "can" and "pretty" and "fly" and "branches" might then become activated. This

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output is compared to target (correct) output, such as "can," "grow," "move," and "fly" all being activated, and no others. The network connections are then adjusted in this direction (they take on values closer to 1), all other connections are incrementally decreased (they take on values closer to 0), and the training process repeats, with new examples.

Typically, training takes place in a series of what connectionist researchers call "epochs," similar to trials of learning. Each epoch follows the procedure just described: An input pattern is presented, and an output pattern of activation is generated, then compared with a correct, target pattern of activation. Connection weights between units are adjusted accordingly, and another input pattern presented to start the next epoch. (For a more detailed and technical discussion of how this training procedure works, consult McClelland, 2000, or Chapter 4 of Clark, 2001; for a more recent example of a connectionist network designed to explore semantic memory, see McRae, 2004).

Let us pause and consider the different models of semantic memory we've just covered. We have seen several proposals for how knowledge is represented. The debate continues over the relative merits of network versus feature models to describe semantic memory. (For reviews, see Chang, 1986; Johnson & Hasher, 1987; Rumelhart & Norman, 1988.) Still, the discovery of semantic priming, the idea of spreading activation, and the experimental innovations designed to test models of semantic memory have all contributed to our understanding of the principles by which knowledge is stored and retrieved. The work reviewed here so far relates directly to another topic in cognitive psychology, the formation and use of concepts to classify information. We will examine this area in more detail in Chapter 8, when we look at other proposals for conceptual representation.

## ■ SCHEMATA

Network models are not the only way of depicting or representing knowledge in semantic memory. Other psychologists, dating back to Sir Frederick Bartlett (1932), invoke the concept of a schema, as we saw in Chapter 6. The term *schema* usually refers to something larger than an individual concept. Schemata (the plural of *schema*) incorporate both general knowledge about the world and information about particular events. Bartlett (1932) defined a schema as an "active organization of past reactions, or of past experiences, which must always be supposed to be operating in any well-adapted organic response" (p. 201). The key term here is *organization*. A **schema** is thought to be a large unit of organized information used for representing concepts, situations, events, and actions in memory (Rumelhart & Norman, 1988).

Rumelhart and Ortony (1977) viewed schemata as the fundamental building blocks of cognition, units of organized knowledge analogous to theories. Generally, they saw schemata as "packets of information" that contain both variables and a fixed part. Consider a schema for the concept *dog*. The fixed part would include the information that a dog is a mammal, has (typically) four legs, and is domesticated; the variables would be things like breed (poodle, cocker spaniel, Bernese mountain dog), size (toy, medium, extra large), color (white, brown, black, tricolored), temperament (friendly, aloof, vicious), and name (Spot, Rover, Tandy). Just and Carpenter (1987) compared a schema to a questionnaire with blanks that a person is supposed to fill in. Labels next to the blanks indicate what sort of information to fill in—for example, name, address, and date of birth.

Schemata can also indicate the relationships among the various pieces of information. For example, to end up with a dog, the "parts" of the dog (tail, legs, tongue, teeth) must be put together in a certain way. A creature with the four legs coming out of its head, its tail sticking out of its nose, and its tongue on the underside of its belly would not "count" as an instance of a dog, even if all the required dog parts were present.

Moreover, schemata can be connected to other schemata in a variety of ways. The schema for my dog, Tandy, for instance, is a part of a larger schema for dogs I have owned (Tandy, Bussey, Eskie, Flit, Tackle), which in turn is part of a larger schema of Bernese mountain dogs, which is part of a still larger schema of dogs, and so on. The schema for Bernese mountain dogs can also be connected with similar, related schemata, such as the one for Saint Bernard dogs (both breeds come from the canton of Bern, Switzerland) or the one for Rottweiler dogs (both classified as "working" breeds by the American Kennel Club and other registries).

Schemata also exist for things bigger than individual concepts. For example, consider meeting a new college roommate for the first time. Your knowledge of such an event can be said to be guided by a schema. Included in this schema would be the fixed part (the setting, a dormitory room; the characters, two students) and the variables (the opening conversation—"Hi. I'm Jane. Are you Susan?"; the sex of the students; the type of room; whether the students have previously talked or corresponded; whether parents are present).

Furthermore, schemata fill in *default values* for certain aspects of the situation, which let us make certain assumptions. For instance, student ages were not given. Lacking such specification, many readers would assume the two students were first-year students. This assumption would be the default value for the variable. Notice, however, that the default can be overridden simply by mentioning other values in the description of the situation.

Schemata are assumed to exist at all levels of abstraction; thus schemata can exist for small parts of knowledge (what letter does a particular configuration of ink form?) and for very large parts (what is the theory of relativity?). They are thought of as active processes rather than as passive units of knowledge. They are not simply called up from memory and passively processed. Instead, people are thought to be constantly assessing and evaluating the fit between their current situation and a number of relevant schemata and subschemata.

Some researchers think schemata are used in just about every aspect of cognition. Schemata are deemed to play an important role in perception and pattern matching as we try to identify the objects we see before us. They are considered important in memory functioning as we call to mind relevant information to help us interpret current information and make decisions about what to do next. We will see in Chapter 10 as well that schemata are thought to explain some aspects of text and discourse comprehension as we try to follow the meaning of a conversation, story, or textbook.

## Scripts

One kind of schema, a schema for routine events, has been called a **script** (Schank & Abelson, 1977). Consider the best-known example of a script: going to a restaurant. Think for a moment (and even better, before reading further, make a few notes) about what happens when you go to a restaurant. Now do the same thing for these other events: attending a lecture, getting up in the morning, grocery shopping, and visiting a doctor. Schank and Abelson (1977) noticed that people's knowledge of what is involved in going to a restaurant was widely shared and was structured in very similar ways. They explained this similarity by saying that people share scripts.

Scripts are thought to be used in a variety of situations. For instance, if you go to a new restaurant, in a city you've never visited before, you can call on a script to tell you what to expect. In general, you should expect on entry to be greeted by a host or hostess, shown to a table when one is available, given menus, and so on. This knowledge cues you for how to behave appropriately. So if you enter a restaurant but don't see a host or hostess, it is normally a good idea to wait (at least a little while) before sitting down; your script tells you this.

Scripts also let us make a number of inferences (Rumelhart & Norman, 1988). Consider this story: "Tim really wanted a chicken-fried steak. So he went to a restaurant and ordered it. Finally, he asked for the check, paid it, and left." Other, apparently omitted information can be inferred by use of the script. For instance, we can infer that Tim entered the restaurant and was seated, that someone took and delivered his order, that someone cooked his steak, that he had money before entering the restaurant, and so on. The story didn't need to say all this, because it gave enough information for us to call up the appropriate script ("going to a restaurant"), and that script filled in the rest.

Bower, Black, and Turner (1979) showed that if information from a story was presented in scrambled order, people tended to recall it in the scripted order. In a further experiment, the investigators presented stories that mentioned only some of the events in a typical script. They found that in a later recall task, participants often "recalled" information that wasn't in the story but was in the relevant script.

The preceding finding was replicated in a study by Owens, Bower, and Black (1979). They presented participants with stories about a character's doing such routine things as making coffee, visiting a doctor, and going to a lecture. Participants in the experimental condition read a three-line description of a problem, such as "Nancy woke up feeling sick again, and she wondered if she really was pregnant. How would she tell the professor she had been seeing? And the money was another problem." Participants were later asked to recall the stories as close to verbatim as possible. Participants who read the problem description recalled more of the story episodes than control participants but also "recalled" more than was in the stories. These intrusions appeared to come from the underlying scripts (e.g., of a young pregnant woman) and became more frequent with longer retention intervals.

The authors suggested that although scripts play an important role in helping us organize recall, they force us to pay a price: other, script-related information intruding into our memory. Thus part of the reason Bartlett's participants produced such distorted recalls of "The War of the Ghosts" (discussed in Chapter 6) is that they used their schemata and scripts for stories and "regularized" the original folktale, making it conform more to their own cultural expectations of how a story should proceed.

## ■ IMPLICIT VERSUS EXPLICIT MEMORY

We have already seen that some psychologists favor making a distinction between two types of memory: episodic and semantic. Some psychologists also distinguish between declarative and procedural memories. Many argue these kinds of memory form different systems; that is, they operate on different principles, store different kinds of information, and so on. Others disagree, declaring there is no compelling reason to believe that more than one *type* of memory exists.

Other cognitive psychologists have proposed another distinction between kinds of memory: implicit and explicit (Roediger, 1990; Schacter, 1987). **Explicit memories** are things that are consciously recollected. For example, in recalling your last vacation, you explicitly refer to a specific time (say, last summer) and a specific event or series of events. Your recall is something you are aware of and may even be something deliberate. **Implicit memory,** by contrast, is memory that is not deliberate or conscious but shows evidence of prior learning and storage. Schacter (1996) poetically described implicit memory as "a subterranean world of nonconscious memory and perception, normally concealed from the conscious mind" (pp. 164–165).

Laboratory work on implicit memory has been mainly concerned with a phenomenon known as *repetition priming*. We've already reviewed the phenomenon of **semantic priming,** in which exposure to one word (for example, *nurse*) facilitates the recognition or other cognitive processing of a semantically related word (for example, *doctor*). **Repetition priming** is priming of a somewhat different sort: facilitation of the cognitive processing of information after a recent exposure to that same information (Schacter, 1987, p. 506). For example, participants might be given a very brief exposure (of 30 milliseconds or less) to a word (such as *button*) and soon afterward be given a new word completion task (for example, "Fill in the blanks to create the English word that comes to mind: *_U _T O_*"). This task is called a *word stem completion* task. The repetition priming effect is demonstrated by an increased probability of responding "button" to the stimulus given in the word completion task, relative to the performance of participants not shown the word *button*. (Note that there are other possible ways to complete the word, such as *mutton* or *suitor*.)

Research on repetition priming has yielded several findings relevant to the topic of knowledge representation. The first is that nonwords typically show no or little repetition priming relative to real words. Thus exposing a participant to a stimulus such as *daxton* will probably not prime the participant to recognize or remember it later. Presumably, this is because *daxton* is not a word and therefore has no associated node in semantic memory that can be activated. A second finding is that priming is greater for words that share the same morphology, or roots of meaning, than for words that are visually or aurally similar. Thus a stimulus such as *sees* can prime responses to *seen* (a word that shares meaning with *sees*) but not to *seed* (a visually similar stimulus) or *seize* (a similar-sounding stimulus).

Do laboratory demonstrations of implicit memory have any real-world relevance? Investigators who study implicit memory believe so. One real-world example of implicit memory was reported by Sergei Korsakoff, who in 1889 described patients with amnesic symptoms that have come to be known as *Korsakoff's syndrome*. One patient to whom he had administered an electric shock professed not to remember the shock but, on seeing the case containing the shock generator, told Korsakoff that he feared Korsakoff had probably come to electrocute him (Schacter, 1987, pp. 503–504).

Other work with amnesic patients demonstrated findings to support the idea of a dissociation between implicit and explicit memory. For example, Warrington and Weiskrantz (1970) conducted a more controlled investigation: They presented a variety of memory tasks to four amnesic patients, as well as to eight patients without brain damage who served as a control group. In one experiment (Experiment 2), participants received two "explicit memory" tasks (the quotation marks indicate the authors did not use this term to describe them), a free-recall task and a recognition task, similar to those described in Chapter 5.

Participants also worked on two "implicit memory" tasks. One was a word completion task, similar to the one just described. The other presented participants with words in which the letters were visually degraded; they were asked to guess the word being displayed. All four tasks involved a prior presentation of various words. In the two "explicit" tasks, participants were asked to recall consciously or recognize the words previously presented. In the two "implicit" tasks, participants were *not* reminded of the prior presentation of words but merely asked to guess the word being presented (that is, in degraded letters or partially, by a word stem).

Figure 7-8 presents the results. It shows quite clearly that amnesic participants performed more poorly than nonamnesic participants on the explicit memory tasks but quite comparably to nonamnesic participants on the implicit memory tasks. In other words, their amnesia seemed to selectively hurt performance on explicit memory tasks. These results have been replicated several times and on a variety of tasks (Shimura, 1986).

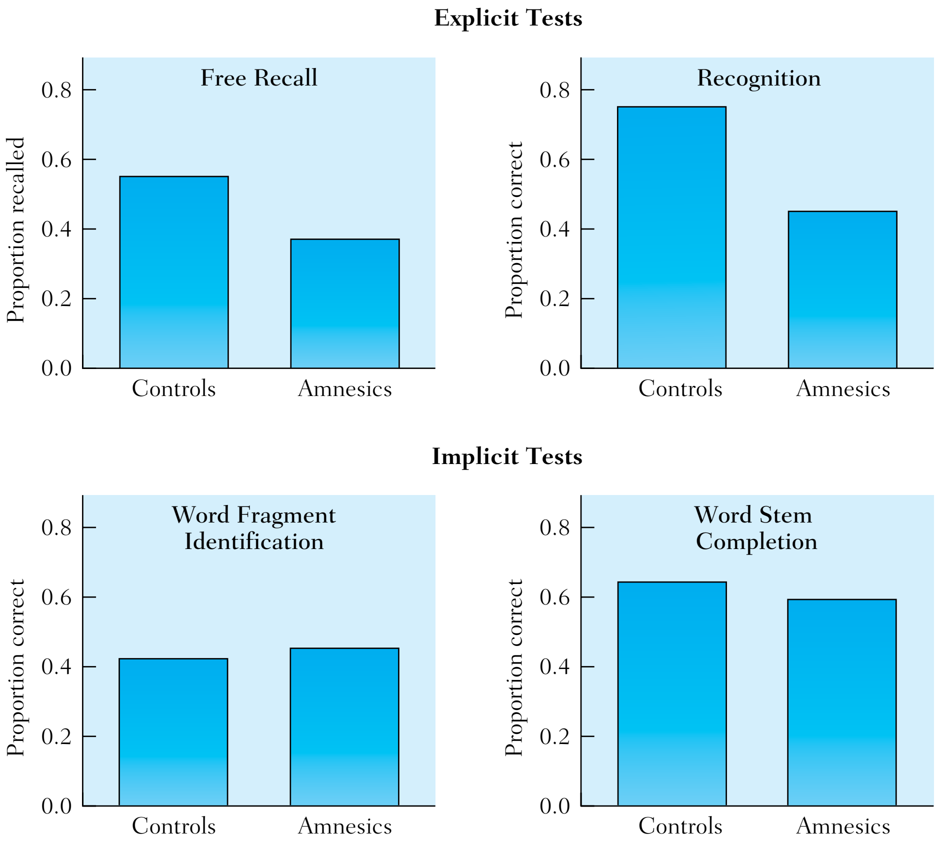
Phenomena such as the one depicted in Figure 7-8 are sometimes called "dissociative," because performance on one task appears independent of (or dissociated from) performance on another. Dissociative phenomena do not by any means occur only with amnesic participants. Many studies (reviewed by Roediger, 1990) have demonstrated striking differences in performance on implicit and explicit memory tasks with normal participants. Schacter (1996) reported that repetition priming effects could persist as long as an entire week, even when his experimental participants denied that the primed words had been previously seen in the laboratory!

How are such dissociation phenomena best explained? Roediger (1990) presented two distinct possibilities. One is to postulate two memory *systems,* such as declarative and procedural memory, and to assert that explicit memory tasks rely on the former and implicit memory tasks rely on the latter. Schacter (1996) even speculated that different brain structures are associated with the two different memory systems. The dissociation in performance on the two tasks would then be assumed to reflect that two memory systems operating in different ways are at work.

The second possibility is that the two kinds of memory tasks require different cognitive procedures, although they both tap into a common memory system (Roediger, 1990). One idea consistent with this proposal is that most implicit memory tasks require *perceptual* processing (that is, interpreting sensory information in a meaningful way) and that explicit memory tasks require *conceptual*

**FIGURE 7-8** ■ *Results from the Warrington and Weiskrantz (1970) study; figure created by Roediger (1990).*

**SOURCE:** Warrington and Weiskrantz (1970, p. 630).



processing (in other words, drawing on information in memory and the knowledge base). In this view, the type of processing required in the two types of tasks explains dissociation phenomena. Much debate focuses on the question of whether the two approaches can be reconciled (Schacter, 1989; Whittlesea & Price, 2001). Essentially, this debate hinges on whether there are multiple and distinct systems of memory, each operating on different principles, or a single memory system that supports different kinds of processing.

## The Process Dissociation Framework

Jacoby and his colleagues (Hay & Jacoby, 1996; Jacoby, 1991, 1998; Toth, Lindsay, & Jacoby, 1992; Toth, Reingold, & Jacoby, 1994) took issue with the idea that implicit memory and explicit memory represent two distinct memory systems and argued for what he called the **process dissociation framework.**

Jacoby asserted that the fact that people perform differently on implicit memory tasks from the way they do on other memory tasks does not point to the existence of an implicit memory. His claim rested on the idea that implicit memory tasks of the sort used by Schacter, Warrington and Weiskrantz, and others are not necessarily *pure* measures of any memory system. Any task relies on a combination of abilities; rarely, if ever, can any test be constructed that measures *only* the aspect it is intended to measure. As an example, consider the last midterm exam you took. Although this test was, I hope, a valid and reliable test of the subject matter (calculus, history, music, or whatever), the test also reflected some of your other abilities (for example, to read, to recall relevant information).

Jacoby (1991) preferred to think about memory tasks as calling on two different processes: intentional and automatic ones. The parallel here with the topic of attentional versus controlled processing reviewed in Chapter 4 is very much by design:

> Performance on direct [that is, explicit] tests of memory typically requires that people intentionally recollect a past episode, whereas facilitation on indirect [implicit] tests of memory is not necessarily accompanied by either intention to remember or awareness of doing so. This difference between the two types of test can be described in terms of the contrast between consciously controlled and automatic processing. (pp. 515–516)

Jacoby (1991) argued that some memory tasks, such as one in which you try to recall a specific incident or fact, involve a great deal of conscious intention. Other tasks, such as judgments of familiarity (for example, the kind of task where you are asked if you've ever seen or heard a stimulus before), involve much more automatic processing. However, each task could draw on both intentional and automatic processing. As you try to recall a specific formula for a test, for instance, you might write down what you think it is, then see if what you've written looks familiar. Conversely, if you are a participant in an implicit memory experiment who is asked to fill in the blanks to make a word out of __ *Z* __ *L E*__, you actually might briefly recall having seen the word *azalea* just a day ago in the same laboratory.

Jacoby (1991) adopted a procedure similar in structure to those used in some of the attentional work we examined in Chapter 4. He tried to set up tasks in which automatic memory processes would either facilitate or hinder performance on an intentional memory task. Automatic processes are commonly described as arising when one is distracted or inattentive; controlled processes occur when one is focused, alert, and intentional about performing a particular task.

Some of Jacoby's best-known work comes from what have been called his "false fame" experiments (Jacoby, Woloshyn, & Kelley, 1989). Participants are shown a list of names of people, none of whom were famous (for example, Sebastian Weisdorf). Some participants are asked to study this list with full attention; others, in a divided-attention task. Later, all participants are given a new list of names, which includes names of famous people, names from the previously studied list (which they are told consisted only of nonfamous people), and names never before seen that were nonfamous, and they are asked to judge the fame of each name on this new list.

Participants in the divided-attention condition were more likely to falsely attribute fame to those names that had been previously studied. Jacoby et al. (1989) interpreted this as evidence for an automatic memory process. Their reasoning was as follows: Participants in the full-attention condition knew that names from the studied list were nonfamous and, moreover, had better recollection of just what names had been studied. Therefore, they consciously used that information in judging those names as being nonfamous. Participants in the divided-attention condition did not learn the list of names as well; when encountering the second list, they did not have as clear memories for whether a particular name was on the studied list. They instead used their familiarity with the name (which resulted from an automatic memory process only) as a basis for judging fame. Unfortunately, exposure to the names on the study list increased the familiarity of those names too, and later these were falsely judged to be famous.

Marcia Johnson and her colleagues (Johnson, Nolde, & De Leonardis, 1996) have come to similar conclusions in their work on **source-monitoring errors.** Briefly, these researchers are interested in people's inability to remember the original *source* of their memories—where they originally obtained the information. For example, imagine you attend a lecture on Sigmund Freud, in which the lecturer gives some biographical information. Later that week, you watch a PBS special about the father of psychoanalysis, which presents similar, but not identical, biographical information. You could later come to believe that the source of your information, say, that Freud was born in 1856, came from the lecturer, when it really was presented in the television program.

Johnson calls this inability a source-monitoring failure and regards it as a very important cause of memory errors. Johnson's explanation for source-monitoring failures goes something like this: When information in long-term memory is activated, it is nonetheless incomplete or ambiguous or both. When we try to determine whether something is a bona fide memory or simply a story we've heard, we may judge this simply on the basis of general familiarity. But, as Jacoby has suggested, using familiarity as a basis for judgment is not a foolproof evaluation metric, and sometimes it leads to error.

We can expect much research in this area in the coming years. Questions such as "What is the nature of the mental representation?" "Which inferences are easy to make using general knowledge, and which inferences are harder?" and "How does knowledge representation change as a function of practice and expertise?" must all be answered. Knowledge representation and organization are critically important to cognitive psychologists. For one thing, the issue of how knowledge is mentally represented underlies the important question "What is common sense?" Workers in artificial intelligence are discovering over and over again that a truly intelligent program or system must have a wide and deep knowledge base and must be able to store and retrieve a great deal of information about the world. The knowledge base must be organized efficiently. So far, the only creatures who have demonstrated efficient organization of such vast knowledge bases are human beings. The challenge now is to find out just how we accomplish this marvelous feat.

## SUMMARY

1. There are a number of different theoretical frameworks and empirical tests of the ways in which information in permanent memory is stored and organized. Three distinct proposals for dividing memory into systems function quite differently, as follows.
2. Tulving's proposal divorces *episodic memory* from *semantic memory,* seeing the latter as a storage of permanent knowledge. In this framework, knowledge is deemed to consist of a number of interrelated ideas, each comprising, typically, smaller units that correspond to the basic "packets" of meaning. The various models—hierarchical networks, feature lists, propositional networks, schemata, scripts—differ on the exact structure of the mental representation but generally agree that the "basic" unit of information represented is at the level of the individual word or concept. Connectionist models, in contrast, deny that concepts are represented as individual units, but rather, suggests they are represented as patterns of activation across different units.
3. A second proposal for separate memory systems distinguishes between *declarative* (knowing that *X* . . . ) and *procedural* (knowing how to do *X*) memory. In this proposal, general knowledge is stored in declarative memory. Theorists often assert that declarative memory is organized as something analogous to a propositional network.
4. A third proposed division of memory distinguishes between *explicit* and *implicit* memory: The former refers to conscious recollections; the latter, to facilitation in performance as a function of past learning without awareness of that past learning. In this proposal, implicit memory phenomena have been seen as ways of determining how general knowledge is organized.

5. How well these three proposals fit together is a matter of some debate. For instance, semantic memory can be mapped onto declarative memory. One might propose that explicit memory relies on this declarative/semantic base. Procedural memory might be involved in implicit memory phenomena. Alternatively, one could argue that episodic memory is the basis for explicit memory of autobiographical events and that semantic memory is involved in many implicit memory tasks. It is also possible to reject the proposals for distinct memory systems.
6. Some have argued against associating different memory *tasks* with different memory systems. Jacoby (1991) believed the best way of understanding memory processes is to distinguish between automatic and intentional memory processes.
7. Clearly, despite the existence of a number of complex, logically crafted models of knowledge representation and organization, we are a long way from a satisfying account of how these processes work.

## REVIEW QUESTIONS

1. Describe the semantic/episodic memory distinction, and discuss the reasons why some psychologists make the distinction and others don't.
2. Contrast the hierarchical semantic network model of semantic memory (Collins & Quillian) with the feature comparison model (Rips, Shoben, & Smith), noting which experimental findings each explains and which findings each is less able to explain.
3. Explain the concept of spreading activation, and review the evidence that leads some psychologists to maintain that it is a property of semantic memory.
4. The research on knowledge representation typically involves laboratory research with people working on somewhat artificial tasks (for example, lexical decision, sentence verification). Does such research have much bearing on cognition in real life? Defend your answer, and use specific examples to illustrate your points.
5. What are schemata and scripts? How might they account for memory for autobiographical events, such as those discussed in Chapter 6?
6. Describe how evidence from neuropsychological studies can be used to illuminate debates over the existence of different memory systems. What are some possible limitations of these studies?
7. Describe the distinction between declarative and procedural memory and that between implicit and explicit memory. Do these two distinctions fit together well? How or how not?

## KEY TERMS

adaptive control of thought (ACT) model of memory
characteristic feature
cognitive economy
declarative memory
defining feature
episodic memory
explicit memory
feature comparison model of semantic memory
hierarchical semantic network model of semantic memory
implicit memory
lexical decision task
lexicon
memory systems
procedural memory
process dissociation framework
production rules
repetition priming
schema
script
semantic memory
semantic network
semantic priming
source-monitoring error
spreading activation
typicality effect

## CogLab DEMONSTRATIONS

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

The **Lexical Decision** task is presented in the CogLab demonstration by the same name.

## WEB RESOURCES

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

## CHAPTER 8

# Concepts and Categorization

**Theoretical Descriptions of the Nature of Concepts**

- The Classical View
- The Prototype View
- The Exemplar View
- The Schemata View
- The Knowledge-Based View

**Forming New Concepts and Classifying New Instances**

- Concept Attainment Strategies
- Acquiring Prototypes
- Implicit Concept Learning
- Using and Forming Scripts
- Psychological Essentialism

If your college or university is like the one where I teach, you probably have to fulfill certain graduation requirements—among them, distribution requirements, which mandate your taking a certain number of courses in each of several groups. For example, Carleton College has four distribution groups: arts and literature (including most courses in studio art, art history, English, literature in translation, literature in foreign languages, and music), social sciences (including educational studies, economics, political science, psychology, and sociology/anthropology), natural science and mathematics (including astronomy, biology, computer science, chemistry, geology, mathematics, and physics), and humanities (including history, philosophy, and religion). The groupings of subject matter into larger distribution groups illustrates my college's categorization, or assignment of courses to groupings.

Of course, not all colleges have the same groups or the same assignment of courses to groups. For example, at other schools my home discipline, psychology, is often assigned to the natural sciences division. At many schools, arts and humanities are grouped together. I'm not entirely sure how the Carleton grouping came to be, but I am sure the dean or committee that created it had a mental representation of this category, something that a cognitive psychologist would call a *concept*.

We have encountered the idea of mental representations several times before. We have seen that many cognitive psychologists (particularly those within the information-processing paradigm) believe that such representations guide cognitive processing and behavior. How you regard something may often be influenced by what type of thing you believe it to be. For example, you would probably react and behave one way if told that a severe thunderstorm was taking place outside, and another way if you were told it was a hurricane. Your classification of storms into two categories suggests that you see distinctions between them. Presumably, such distinctions cause your reactions to storms to depend on classification.

A related, real-life example comes from medical diagnosis. Suppose you wake up one day feeling achy, lethargic, congested, and feverish. Your symptoms could indicate nothing more serious than flu. Or your symptoms could be the harbinger of a much more serious illness. It is your doctor's job to make the diagnosis, which essentially is to assign your pattern of symptoms to a category corresponding to known diseases or medical problems. The categorization allows the physician to determine appropriate treatment and predict the time course of recovery. To make the diagnosis, your physician must have an idea of the various categories (possible medical problems) to be considered. Indeed, physicians are not the only ones who categorize illnesses, as shown by a recent study of laypeople's categorization of forms of mental illness (Kim & Ahn, 2002).

In this chapter, we'll look at concepts and how they are formed. We'll examine different theoretical descriptions of how concepts are structured and their implications for how we assume our mental representations work. We'll then focus on how concepts are accessed and used in categorizing new objects, patterns, or events. Many ideas discussed in the early part of the chapter will extend and elaborate on proposals presented in Chapter 3, "Perceiving Objects and Recognizing Patterns" (pattern recognition and classification have many similarities, as we shall see), and in Chapter 7, "Memory for General Knowledge." Similarly, our examination of categorization will anticipate some later discussions about language, thinking, reasoning, and decision making (Chapters 10–13). You can probably already see that an understanding of how people form and use concepts is relevant to several other cognitive processes and abilities. Medin (1989) has in fact argued that "concepts and categories serve as building blocks for human thought and behavior" (p. 1469). Lamberts and Shanks (1997) have argued that the issue of how things such as concepts are mentally represented is a central concern of cognitive psychology.

What are concepts and categories, and how do they differ? The distinction turns out to be a little blurry but can still be made. Medin (1989) defined a concept as "an idea that includes all that is characteristically associated with it" (p. 1469). In other words, a **concept** is a mental representation of some object, event, or pattern that has stored in it much of the knowledge typically thought relevant to that object, event, or pattern. Most people's concept of "dog," for example, would include information to the effect that a dog is an animal, has four legs and a tail, has a reputation as "man's best friend," is a common pet, and so on.

A **category** can be defined as a class of similar things (objects or entities) that share one of two things: either an essential core (example: why all science courses are considered "science") or some similarity in perceptual, biological, or functional properties (Lin & Murphy, 2001). When a psychologist thinks about categories, she usually thinks about several different ones, into which various things get sorted. In the game 20 Questions, a common opener is, "Is it an animal, vegetable, or mineral?" This question seeks to categorize, or sort, the to-be-guessed item into one of three things. Sometimes categories are described as existing objectively in the world, and concepts are described as mental representations of categories (Medin, 1989).

Concepts help us establish order in our knowledge base (Medin & Smith, 1984). Concepts also allow us to categorize, giving us mental "buckets" in which to sort the things we encounter, letting us treat new, never-before-encountered things in the same way we treat familiar things that we perceive to be in the same set (Neisser, 1987). Categorization also allows us to make predictions and act accordingly. If I see a four-legged creature with a tail coming toward me, my classification of it as either a dog or a wolf has implications for whether I'll want to call to it, run away, pet it, or call for help. Smith and Medin (1981) elaborated on the important role concepts play in our mental life:

> Without concepts, mental life would be chaotic. If we perceived each entity as unique, we would be overwhelmed by the sheer diversity of what we experience and unable to remember more than a minute fraction of what we encounter. And if each individual entity needed a distinct name, our language would be staggeringly complex and communication virtually impossible. Fortunately, though, we do not perceive, remember, and talk about each object and event as unique, but rather as an instance of a class or concept that we already know something about. (p. 1)

We will first examine different theoretical accounts about the nature and structure of concepts. Next, we'll look at how concepts are formed or acquired. Finally, we'll examine how people actually use concepts through the process of categorization. Throughout this chapter, we'll be focusing on concepts of objects and nouns, because they are the most commonly studied at present in cognitive psychology. We will see, however, that the kind of concept studied may affect the concept theories that are subsequently created. So it will be useful to keep in mind that psychologists have yet to explore fully the entire range of people's concepts.

## ■ THEORETICAL DESCRIPTIONS OF THE NATURE OF CONCEPTS

In Chapter 7, we reviewed proposals for how our knowledge bases are represented and organized. Models of semantic memory describe the ways in which representations of different concepts are interrelated. Here we will concentrate on the representation and organization of individual concepts. We will explore five distinct proposals on how concepts are represented and structured. Each one provides a different answer to the question "What information do we have when we have a particular concept?" Each proposal will therefore have different implications for the question of how concepts are formed, acquired, or learned.

### The Classical View

The classical view of concepts was the dominant view in psychology up until the 1970s and dates back to Aristotle (Smith & Medin, 1981). This proposal is organized around the belief that all examples or instances of a concept share fundamental characteristics, or **features** (Medin, 1989). In particular, the **classical view of concepts** holds that the features represented are individually necessary and collectively sufficient (Medin, 1989). To say a feature is individually necessary is to say that each example must have the feature if it is to be regarded as a member of the concept. For example, "has three sides" is a necessary feature of the concept *triangle;* things that do not have three sides are automatically disqualified from being triangles. To say that a set of features is collectively sufficient is to say that anything with each feature in the set is automatically an instance of the concept. For example, the set of features "has three sides" and "closed, geometric figure" is sufficient to specify a triangle; anything that has both is a triangle. Table 8-1 presents some other examples of sets of features or of concepts that are individually necessary and collectively sufficient.

The classical view of concepts has several implications. First, it assumes that concepts mentally represent lists of features. That is, concepts are not representations of specific examples but rather abstractions containing information about properties and characteristics that all examples must have. Second, it assumes that membership in a category is clear-cut: Either something

**Table 8-1** Examples of Concepts and Their Features

| | *Bachelor* | *Triangle* | *Uncle* | *Prime Number* |
|---|---|---|---|---|
| *Concept* | Male | Geometric figure | Male | Integer divisible by two numbers: itself and 1 |
| *Features* | Adult<br>Unmarried<br>Human | Three-sided<br>Planar | Sibling<br>One or more siblings has a child | |

has all the necessary and sufficient features (in which case it is a member of the category), or it lacks one or more of the features (in which case it is not a member). Third, it implies that all members within a category are created equal: There is no such thing as a "better" or "worse" triangle.

Work by Eleanor Rosch and colleagues (Rosch, 1973; Rosch & Mervis, 1975) confronted and severely weakened the attraction of the classical view. Rosch found that people judged different members of a category as varying in "goodness." For instance, most people in North America consider a robin and a sparrow very good examples of a bird but find other examples, such as chickens, penguins, and ostriches, not as good. Notice the problem this result presents for the classical view of concepts. The classical view holds that membership in a category is all-or-none: Either an instance (such as robin or ostrich) belongs to a category, or it doesn't. This view has no way to explain people's intuitions that some birds are "birdier" than others.

People's judgments of typicality, the "goodness" of the instance in the category, was later shown to predict several aspects of their performance on different tasks. For example, participants in a sentence verification task were faster to respond (true or false) to a sentence such as "A robin is a bird" than to a sentence such as "A chicken is a bird" (McCloskey & Glucksberg, 1978; Rosch, 1973; Smith et al., 1974). Asked to list instances of a concept, people were more likely to list typical than atypical instances (Mervis, Catlin, & Rosch, 1976). In semantic priming studies (see Chapter 7 for a review), highly typical instances often led to better priming (Rosch & Mervis, 1975; Rosch, Simpson, & Miller, 1976).

All these results are not easily explained within a classical framework. In addition, other studies cast doubt on the idea that people typically store and refer to a list of necessary features when judging category membership. McCloskey and Glucksberg (1978) gave participants a list of items and asked them to judge whether the items belonged to certain categories (for example, "Does 'chair' belong to the category 'furniture'?"). The classical view would predict very strong agreement across people, but McCloskey and Glucksberg's participants in fact disagreed considerably on atypical instances (for example, "Do 'bookends' belong to the category 'furniture'?"). Participants were often inconsistent in their own responses in different sessions. This result argued especially strongly against the classical assumption that categories have clearly defined boundaries. Finally, even when given specific instructions to do so, most people cannot generate lists of features that are individually necessary and collectively sufficient to specify membership in a category (Ashcraft, 1978; Rosch & Mervis, 1975).

## The Prototype View

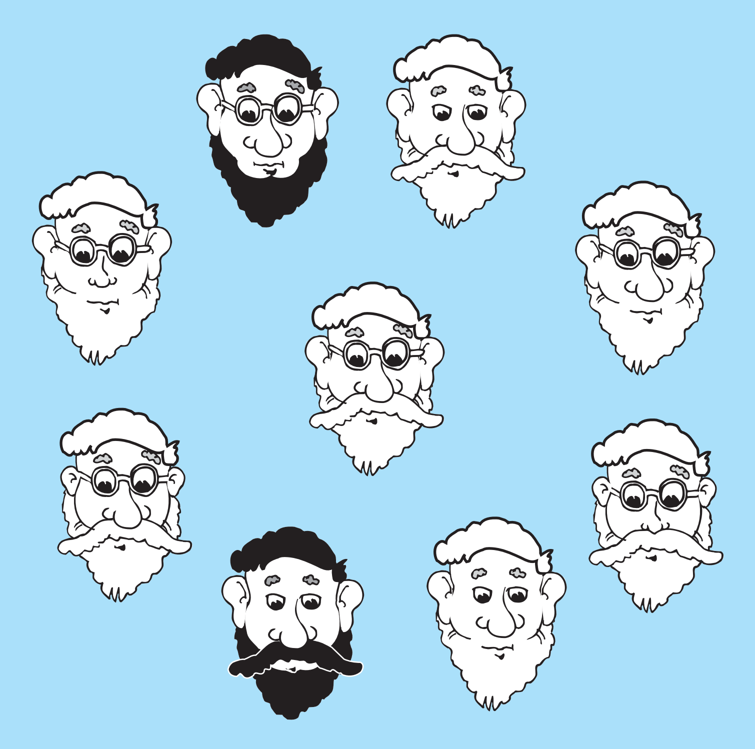
A second theoretical view of the nature of concepts, known as the *prototype view,* was proposed in the 1970s. The **prototype view of concepts** denies the existence of necessary-and-sufficient feature lists (except for a limited number of concepts such as mathematical ones), instead regarding concepts as a different sort of abstraction (Medin & Smith, 1984). Like perceptual researchers (see Chapter 3), conceptual researchers believe in the existence of mental **prototypes,** idealized representations of some class of objects or events. Specifically, researchers studying the prototype view of concepts hold that prototypes of concepts include features or aspects that are *characteristic*—that is, typical—of members of the category rather than necessary and sufficient. No individual feature or aspect (except very trivial ones, such as "is an object") need be present in the instance for it to count as a member of the category, but the more characteristic features or aspects an instance has, the more likely it is to be regarded as a member of the category.

The prototype view of concepts and categories often refers to the **family resemblance structure of concepts** (Wittgenstein, 1953), a structure in which each member has a number of features, sharing different features with different members. Few, if any, features are shared by every single member of the category; however, the more features a member possesses, the more typical it is. Figure 8-1 provides an example of family resemblance. Note that the Smith brothers (modeled after the men on Smith Bros. Cough Drop boxes) have several shared features: light hair, bushy mustache, large ears, and eyeglasses. Not every Smith brother has every feature, but the brother in the middle, having them all, would likely be judged by Smith friends to be the most typical Smith of the bunch. Note that he shares big ears, eyeglasses, and light hair with the brother in the "ten o'clock" position and a mustache and big ears with the "seven o'clock" brother. Indeed, different pairs of brothers share different features.

The prototype view of concepts explains typicality effects by reference to family resemblance. The idea is that the more characteristic features an instance

**FIGURE 8-1** ■ *An example of family resemblance.*

**SOURCE:** Armstrong et al. (1983, p. 269).



of a concept has, the stronger the family resemblance between that instance and other instances, and therefore the more typical an instance it is. Presumably, then, a robin is thought of as a more typical bird than a penguin because the robin possesses more characteristic bird features, such as "is small," "flies," "eats worms," and "lives in a tree." Even with well-defined concepts such as *bachelor,* some examples seem more bachelorlike than others.

For example, is my 13-year-old son Tim a good example of a bachelor? He is male and unmarried. And probably, he's a better example of a bachelor today than he was 10 years ago. What about the pope? The point here is that both people may meet the technical definition of a bachelor (there's some disagreement over whether the definition includes "adult"), but neither is as good an example as might be someone such as the current male teenage heartthrob.

In one set of studies, Rosch and Mervis (1975) presented their undergraduate participants with terms (such as *chair, car, orange, shirt, gun, peas*) from six different superordinate categories (such as "furniture," "vehicle," "fruit," "clothing," "weapon," "vegetable") and asked them to list attributes "common to and characteristic of" those objects. So, for example, for the word *chair* a participant might list "has four legs; used to sit in; sometimes has arms; used in homes and offices." Then Rosch and Mervis tallied a list of all the attributes any participant listed for all basic-level terms belonging to a superordinate category (for example, all the attributes listed for *chair, sofa, table, dresser, desk, bed, clock, closet, vase, telephone*). Next, they computed, for each item, the number of attributes commonly listed for it. They found that items such as chair and sofa—ones that seem more prototypical of the superordinate category "furniture" —had many more of the "furniture" attributes listed than did items such as clock or telephone, which are both not at all prototypical examples of furniture. However, very few (0 or 1) attributes in any of the six superordinate categories were true of all 20 items for the category (for example, attributes true of all fruits).

A prototype, then, is some sort of abstraction that includes all the characteristic features of a category. The prototype may or may not be an actual instance of the category. Prototypes are often thought of as mental "summaries" or "averages" of all the instances, although there are some problems with this view (Barsalou, 1985). The general idea of the prototype view, then, is that concepts have one or more "core" representations, based on a family resemblance structure, but have no rigid boundaries.

Rosch and her colleagues (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976) made another important discovery about concepts. Although concepts exist at many different levels of a hierarchy (for example, "Bernese mountain dog," "dog," "canine," "mammal," "animal"), one level of abstraction appears psychologically fundamental. They called this the "basic" level and distinguished it from both higher-level (superordinate) and lower-level (subordinate) concepts.

To understand the distinctions between the **basic level of categorization** and other levels, consider the purpose of categorization. On the one hand, we want to group together similar objects, events, people, ideas, and so on. On the other hand, we want our categorization to distinguish among objects, events, people, and ideas that differ in important ways. There must be some compromise between these two goals. Rosch and colleagues consider the basic level to be the best compromise.

"Piano" and "guitar" are examples of two basic-level categories. Such categories include members that are maximally similar to one another, unlike **superordinate levels of categories** (such as "musical instruments"), which contain members (such as pianos and guitars) that are dissimilar in several respects. At the same time, basic-level categories are most differentiated from one another, especially relative to subordinate categories. "Grand piano" and "upright piano" are two categories at the **subordinate level of categories;** these categories are less distinct than are two basic-level categories, such as "piano" and "guitar." The list in Table 8-2 presents examples of basic-level categories, along with related superordinate and subordinate categories.

## Table 8-2 Basic-Level Categories with Related Superordinate and Subordinate Categories

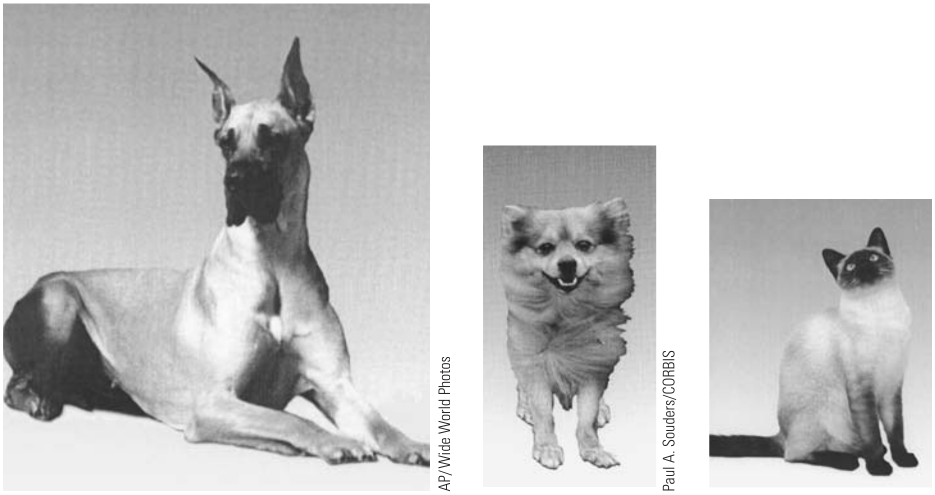
| *Superordinate* | *Basic Level* | *Subordinate* |
|---|---|---|
| Musical instrument | Guitar | Classical guitar<br>Folk guitar |
| | Piano | Grand piano<br>Upright piano |
| | Drum | Bass drum<br>Kettle drum |
| Fruit | Apple | Delicious apple<br>McIntosh apple |
| | Peach | Cling peach<br>Freestone peach |
| | Grapes | Concord grapes<br>Green seedless grapes |
| Tool | Hammer | Claw hammer<br>Ball-peen hammer |
| | Saw | Hack handsaw<br>Cross-cutting handsaw |
| | Screwdriver | Phillips screwdriver<br>Regular screwdriver |
| Clothing | Pants | Levis<br>Double-knit pants |
| | Socks | Knee socks<br>Ankle socks |
| | Shirt | Dress shirt<br>Knit shirt |
| Furniture | Table | Kitchen table<br>Dining room table |
| | Lamp | Floor lamp<br>Desk lamp |
| | Chair | Kitchen chair<br>Living room chair |
| Vehicle | Car | Sports car<br>Four-door sedan |
| | Bus | City bus<br>Cross-country bus |
| | Truck | Pickup truck<br>Tractor-trailer truck |

**Source:** Rosch, Mervis, et al. (1976, p. 388).

The prototype view does a very good job at explaining why certain members of a category are seen as more typical than others. It also explains why people have a hard time providing strict definitions of their concepts: Strict definitions do not exist. Finally, the prototype view can explain why some classifications are especially easy to make and others are unclear. Take tomatoes, which some people classify as a vegetable and others classify as a fruit. Tomatoes are often eaten with other vegetables instead of with other fruits, and they share some similarities with other vegetables. However, to a biologist, tomatoes are a fruit because they develop from the flower of the plant (technically, the pistil). Vegetables, in contrast, are any nonreproductive parts of a plant, such as the stem or root. The prototype view explains the ambiguity of tomatoes: They share features both with vegetables (leading to classification as a vegetable) and with fruits (leading to classification as a fruit).

The prototype view is not wholly free of problems. For one thing, it fails to capture people's knowledge about the limits of conceptual boundaries. To illustrate, even though a Pomeranian seems in many ways more similar to a Siamese cat than to a Great Dane, the Pomeranian and Great Dane are classified together as dogs (Komatsu, 1992). The prototype view has a hard time telling us why. Unlike the classical view, which sets constraints or boundaries around which things can and can't belong to a category, the prototype view does not specify clear constraints.

Rosch and colleagues (Rosch, 1973; Rosch & Mervis, 1975; Rosch, Mervis, et al., 1976) have argued that some constraints around different categories come



AP/Wide World Photos

Paul A. Souders/CORBIS

PhotoDisc

*A Great Dane, a Pomeranian, and a Siamese cat: Even though the overall similarity may be greater between the latter two, the former two are classified together in the category "dogs."*

from the environment itself. Having wings and being able to fly, for example, tend to co-occur, often in those things we call *birds* (but also in airplanes, butterflies, and insects). Boundaries between categories, then, come not just from us as cognitive processors of information but from the way the world works: Certain patterns of attributes or features occur in the world, and others don't (Komatsu, 1992; Neisser, 1987). People's main job in categorizing, then, is to pick up information about the world's regularities, not to impose arbitrary groupings, as the classical view might imply. (The idea of "picking up information" about the world might remind the alert student of Gibsonian theories of perception, discussed in Chapter 3.)

A second problem for the prototype view has to do with typicality ratings. Barsalou (1985, 1987) and Roth and Shoben (1983) showed that the typicality of an instance depends to some extent on context. So although a robin may be seen as a typical bird in the context of birds you see in the neighborhood, it is atypical of birds you see in a barnyard. These findings contrast with the idea that a member of a category has a certain level of typicality. Instead, typicality apparently varies with the way the concept itself is being thought about.

Studies by Armstrong, Gleitman, and Gleitman (1983) demonstrated additional problems with typicality ratings. In these studies, the investigators asked participants to rate the typicality of instances of both natural concepts (such as "vehicle" or "fruit") previously studied by Rosch and her colleagues and of well-defined concepts (such as "even number," "female," "geometric figure"). Armstrong et al. found that participants happily rated the typicality of members of well-defined categories, generally agreeing that 3 is a more typical odd number than 57, for example. The same participants also agreed, however, that the category "odd number" was well defined and that it makes little sense to talk about degree of membership in the category: Numbers either are or are not odd. The investigators concluded that the typicality ratings task is flawed, at least for discovering the underlying representation of concepts.

## The Exemplar View

The previous two views of concepts both hold that concepts are some sort of mental abstraction or summary. In other words, individual instances are not specifically stored or mentally represented but instead are averaged into some sort of composite representation. The **exemplar view of concepts** makes just the opposite assumption: It asserts that concepts include representations of at least some actual individual instances. The exemplar approach assumes that people categorize new instances by comparing them to representations of previously stored instances, called *exemplars*. That is, people store representations of actual instances (Fido, the golden retriever with the long ears; Rover, the black and white sheltie who's missing a tail due to an unfortunate encounter with a raccoon; Precious, the Yorkshire terrier who always has painted toenails and a bow in his hair).

Like the prototype view, it thus explains people's inability to state necessary and defining features: There are none to be stated. It also explains why people may have difficulty categorizing unclear, atypical instances: Such instances are similar to exemplars from different categories (for example, tomato is similar both to fruit exemplars, such as oranges or apples, and to vegetable exemplars, such as beets or squash) or are not similar enough to any known exemplars (Medin & Smith, 1984). Typical instances are thought to be more likely to be stored than less typical ones (Mervis, 1980) or to be more similar to stored exemplars, or both. This explains why people are faster to process information about typical instances. So, in trying to retrieve information about a typical instance, it is faster to find very similar stored exemplars. Atypical instances, in contrast, being rather dissimilar from stored exemplars, take longer to process.

The biggest problem with the exemplar view is that, like the prototype view, it is too unconstrained. It fails to specify, for example, which instances will eventually be stored as exemplars and which will not. It also does not explain how different exemplars are "called to mind" at the time of categorization. However, many psychologists believe people often store information about some specific category members in their conceptual representations, as we will see later.

## The Schemata View

We have already touched on the concept of a schema, or organized framework for representing knowledge, in talking about Bartlett's (1932) work on people's memories for stories (see Chapters 6 and 7), so our coverage here will be brief. Be sure you've understood the material from those chapters on schemata as you read what is here.

The schemata view of concepts is that concepts are schemata—frameworks of knowledge that have roles, slots, variables, and so on. Schemata can embed themselves in one another hierarchically. Thus any schema can have subschemata and/or superschemata. The "meeting a college roommate for the first time" schema can be a subschema of an "orientation to college" schema, which may be embedded in an "attending college" schema, and so on. Similarly, the "meeting a college roommate for the first time" schema may contain subschemata of "dorm room," "meeting new person," and "roommate" embedded within it. The schema for "dog" may be a part of the schemata for "mammal," "pet," "animal," and "living thing"; it may contain subschemata such as "fur," "paws," and "wagging tail." The notion of schemata as underlying organizational units of memory has had significant impact on cognitive psychologists' thinking about how memory is organized and concepts represented. Some (Komatsu,

1992) have seen the **schemata/scripts view of concepts** as sharing features with both the prototype view (in that both schemata and prototypes store information that is abstracted across instances) and the exemplar view (in that both schemata and exemplars store information about actual instances).

The schemata view shares some of the problems facing the prototype and exemplar views. It does not specify clear enough boundaries among individual schemata. Moreover, some psychologists argue that in its current state the schema framework is not sufficiently delineated to be empirically testable (Horton & Mills, 1984). Answers to the following questions are still needed: What kinds of experiences lead to the formation of new schemata? How are schemata modified with experience? How do people know which schemata to call up in different situations—that is, what sorts of environmental cues are used?

## The Knowledge-Based View

A number of cognitive psychologists (Keil, 1989; Lin & Murphy, 2001; Murphy & Medin, 1985) have argued that concepts have much more to do with people's knowledge and worldviews than previously recognized. Murphy and Medin (1985) suggested that the relationship between a concept and examples of the concept is analogous to the relationship between a theory and data supporting that theory. The idea of the **knowledge-based view of concepts** is that a person classifying objects and events doesn't just compare features or physical aspects of the objects and events to features or aspects of stored representations. Instead, the person uses his or her knowledge of how the concept is organized to justify the classification and to explain why certain instances happen to go together in the same category. The knowledge-based view helps explain how an apparently disparate collection of objects can form a coherent category in particular circumstances.

To take an example from Barsalou (1983), consider the category comprising children, pets, photo albums, family heirlooms, and cash. On the face of it, these things don't seem to go together very well, but in the context of a scenario in which a fire is about to engulf a house, these things fall neatly into the category "things to save." We know that each object mentioned is precious to its owner or parents and also irreplaceable. Notice, however, that the category becomes coherent only when we know its purpose.

Recall that the prototype, exemplar, and schemata/scripts approaches to concepts and categories fail to offer much of an answer to the question of how things in the same category go together. The knowledge-based view proposes that people's theories or mental explanations about the world are intertwined with their concepts and provide the basis for categorization (Heit, 1997). This view lets people explain to themselves and to others the instances that go together and why, the features or aspects of instances that are important and why, and the features or aspects that are irrelevant and why.

The five approaches to conceptual structure just reviewed have been themselves categorized into two major types: similarity-based and explanation-based (Komatsu, 1992). The similarity-based category consists of the classical, prototype, and exemplar views (and some parts of the schemata/scripts view). It includes approaches in which categorization is assumed to be based on the similarity of an instance to some abstract specification of the category (such as a definition or a prototype) or to one or more stored exemplars.

However, to say that objects are categorized on the basis of similarity raises some problems, some of which Goodman (1972) pointed out. Consider two objects, a fork and a spoon. We say they are similar, probably because they share many properties: Both are made of metal, both are less than a foot long, and both are used as eating utensils. Now consider two other objects, a plum and a lawnmower. Are these similar? Well, they share several properties: Both weigh less than 100 kilos (and in fact, both weigh less than 101 kilos, 102 kilos, and so forth). In fact, these two apparently dissimilar items share an infinite number of properties (Hahn & Chater, 1997). But the property of weighing less than 100 kilos seems somehow beside the point when you are evaluating the similarity between a plum and a lawnmower. The key point is that similarity is meaningful only in certain respects. But Goodman concluded that the term *similarity* is pretty empty without some specification of what the relevant respects are.

Komatsu (1992) defined a different type of approach to concepts, which he called the *explanation-based category,* comprising some of the schemata/scripts view and some of the knowledge-based view. In this approach to the study of concepts, people are seen as basing classifications on meaningful relationships among instances and categories. The contrast between the similarity-based and the explanation-based approaches has to do with the degree to which people focus on superficial, perceptual information about a particular object versus the degree to which they focus on deeper, knowledge-derived information about an object's function or role.

The five approaches to concepts differ on several dimensions. The first dimension is the cognitive economy of the mental representation. Recall our discussion of cognitive economy from Chapter 7. The idea is to save on mental resources (such as storage space, processing time) by limiting the amount of information we must store. If we treated every single object or event as completely unique, thereby forming a unique mental representation for each, we would not be using our cognitive resources very economically.

In contrast, if we categorized all objects into one category (called "things"), the category wouldn't be very informative. So any theory of concepts and categorization must strike a balance between cognitive economy and informativeness (Komatsu, 1992). At the same time, any theory of concepts must explain a concept or category's coherence—what holds the class of things together into a natural grouping. Some approaches, such as the classical approach, do this very directly; others have fuzzier boundaries around and between concepts.

Thus far, we have looked at different proposals for what concepts are—their nature and structure. In the next section, we will examine empirical studies looking at how concepts are actually formed and used. Presumably, understanding something about the ways in which people classify new instances can shed light on the nature of concepts. The studies we'll review next will help us think more carefully about the five approaches just discussed.

## ■ FORMING NEW CONCEPTS AND CLASSIFYING NEW INSTANCES

To have a concept of something is to group similar things together, to treat in more or less similar ways members of the category that the concept includes. To form a concept, people must have some basis for generalization, for grouping certain things but not others together. When you think about it, forming a concept is a remarkable cognitive achievement. It requires that we figure out which attributes or features of things are relevant and which should be ignored. Often we must carry out the task with very little feedback. In this section, we'll explore some investigations of how people manage this complex undertaking. Throughout, we'll see that psychologists' assumptions about how concepts are mentally represented have influenced their views on how people acquire or form new concepts.

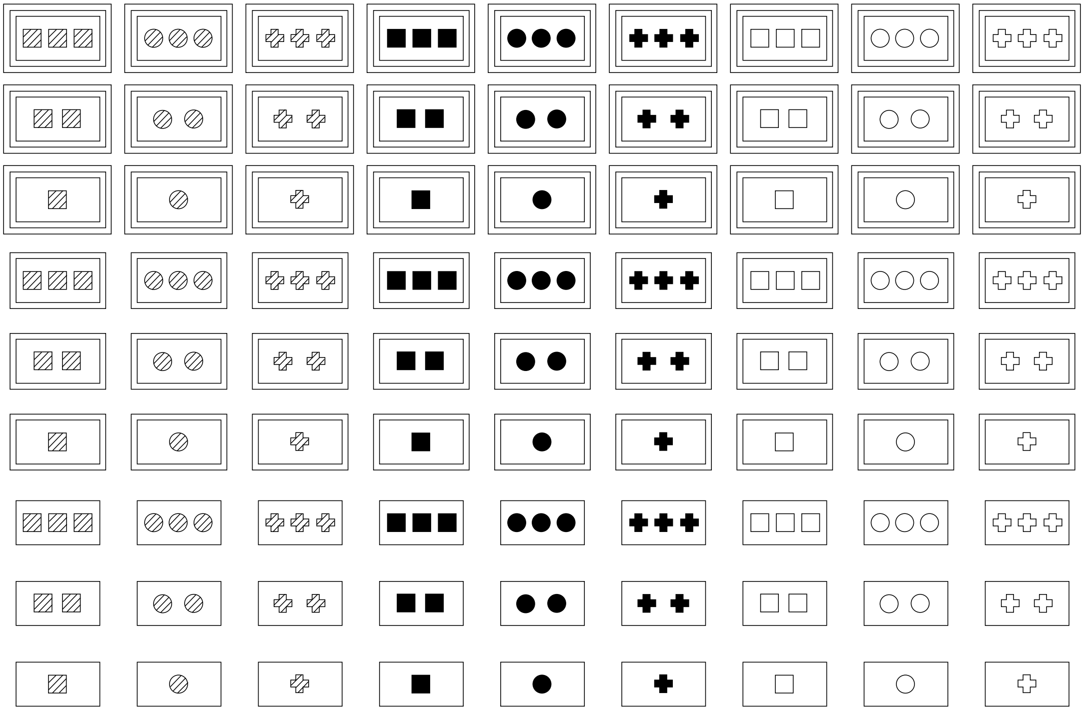
### Concept Attainment Strategies

Bruner, Goodnow, and Austin (1956) conducted some of the earliest work on how people form (or, in their terminology, "attain") concepts. They saw several components in the process: acquiring the information necessary to isolate and learn a concept, retaining the information for later use, and transforming the information to make it usable when testing ideas about new possible instances.

Bruner et al. (1956) studied the ways people attained concepts, using cards depicting differing geometric figures, as shown in Figure 8-2. Note that each card has one of three shapes (circle, square, or cross), one of three colors (here, black, white, or striped), different numbers of shapes (one, two, or three), and different numbers of borders around the shapes (one, two, or three). The experimenter first placed before each participant all the cards appearing in Figure 8-2. Participants were told the experimenter had in mind a certain concept, such as "black circles" or "all cards containing two borders and striped figures." Participants were then shown one card that illustrated the concept—in other

**FIGURE 8-2** ■ *Stimuli used by Bruner et al. (1956).*

**SOURCE:** Bruner et al. (1956).



words, a positive instance. Their subsequent task was to test the other cards, one at a time, for inclusion in the category. The experimenter provided feedback after each card was considered. Each person was asked to determine the nature of the concept as efficiently as possible, choosing cards in any order and offering hypotheses whenever he felt comfortable doing so.

From the participants' choices, Bruner and colleagues tried to determine the strategies used. Bruner et al. (1956) described distinct strategies that could be used to perform the task. They called one strategy *simultaneous scanning*. People who pursued this strategy used each card to test and rule out multiple hypotheses. The strategy required participants to figure out ahead of time the hypothesis to which each card was relevant and to consider carefully how to eliminate the maximum number of hypotheses by choosing the optimal card at each point in the process. As you might expect, this strategy is difficult to use and makes heavy demands on working memory.

A second strategy, *successive scanning*, appeared more manageable. Here, a participant tested one hypothesis at a time. For example, he first tried to see, by choosing appropriate cards, if the concept was "black figures"; if he became convinced this was the wrong concept, he or she tested another idea, and so on, until amassing enough evidence that the correct concept had been attained. The contrast between simultaneous and successive scanning is that the former involves testing a number of ideas at the same time; the latter involves testing ideas one at a time. Successive scanning is therefore less efficient but more cognitively manageable.

A third strategy was called *conservative focusing*. It consisted of finding a card that illustrated the concept (called the "focus" card), then choosing to test other cards that varied from it in only one aspect. For instance, if the focus card had two black crosses and one border, the participant might next select one of the following cards: a card with two black circles and one border; a card with one black cross and one border; a card with two black crosses and two borders; or a card with two white crosses and one border. If any of these cards was also a member of the category, then the participant could logically eliminate the changed attribute as being relevant to the concept. For example, if the card with two white crosses and one border was also a member of the category, then the participant knew color did not define the concept. This strategy is interesting because it is both efficient and relatively easy, but unless the cards are laid out in an orderly fashion so a particular one can be easily located, it may be difficult to carry out.

Bruner et al. (1956) found that the effectiveness of each of these strategies depended to some extent on the task conditions. For instance, when participants had to do the problem "in their heads," without the cards' being displayed, those using scanning strategies had more trouble than did participants who could lay out the cards on a table to refer to as they worked. The strategy participants adopted also depended to some extent on the task, such as whether the cards were initially arranged in an orderly or random way.

Aficionados of the game Mastermind might recognize that it has many basic similarities to the Bruner et al. (1956) concept attainment task. Laughlin, Lange, and Adamopoulos (1982) studied college students playing a simplified version of the game and found that the two dominant strategies that emerged were similar to Bruner and colleagues' conservative focusing and simultaneous scanning. Participants who used these strategies had more success at playing the game than did those who did not, with the conservative focusing strategy being the most successful.

Notice the kind of concept being learned in these tasks. In all the tasks, valid instances of the category share necessary and sufficient features. In fact, the concepts involved in these experiments were what philosophers and psychologists might call *nominal:* concepts that have precise definitions (Schwartz, 1980). The results of the Bruner et al. (1956) studies suggest that when concepts are defined with necessary and sufficient features, people form representations that include necessary and sufficient features. We will see later that

MASTER MIND

Nancy J. Ashmore

*The game of Mastermind is a real-life example of the concept attainment task used by Bruner et al. (1956).*

when people acquire other kinds of concepts, especially those that do not have clear-cut definitions, their acquisition strategies vary.

## Acquiring Prototypes

You may remember that in Chapter 3 we reviewed experiments that Posner and Keele (1968) performed on people's ability to classify dot patterns. Their study suggested that, at least in some circumstances, people are able to, and find it natural to, form prototypes and that they are better able to classify actual prototypes than to classify previously encountered instances. In part of the study, the experimenters began with four specific dot patterns (prototypes): a triangle, the letters *M* and *F,* and a random pattern. Next they created distortions of these patterns by varying the position of the dots. They also varied the number of dots moved, as well as the amount of distortion, sometimes moving each dot very slightly, other times moving dots a great distance.

Undergraduates learned to classify correctly either low-distortion or moderate-distortion stimuli but were never shown the original prototypes. The assumption was that students who saw the low-distortion stimuli ought to have had a better conception of the prototypes than those who saw the moderate-distortion stimuli. Conversely, students in the moderate-distortion group ought to have had a better sense of how much variation there could be from the prototype. Both groups of students were later shown some novel, high-distortion stimuli. Students in the moderate-distortion group were significantly better able to classify these patterns. Further, all students found it easier to classify novel patterns that were similar to prototypes.

These results suggest two things. First, people do form and use prototypes, even when given distorted instances during the learning phase. Second, learning about category variability may be at least as important as learning about prototypes, especially if categorizations are to be made later of new instances that vary a great deal from the prototype.

The results obtained by Posner and Keele (1968) appear very different from those of Bruner et al. (1956). What might account for this difference? Two important differences are apparently the type of stimuli being used and the type of concepts being acquired. Notice that the Bruner et al. task involved concepts with clear-cut definitions; the Posner and Keele task did not. This latter task involved learning concepts that were defined by similarity to previous examples. When categories are defined in this way, people apparently learn to classify by forming and using mental representations of prototypes. Taken as a whole, the results from these studies reinforce the idea that the way people form and learn concepts depends critically on the instances and the categories they must work with.

## Implicit Concept Learning

The results just described imply that people can and do form and use prototypes, at least under certain conditions and with certain stimuli. This raises the question of whether participants ever retain and make use of information about specific exemplars. Arthur Reber (1967, 1976) conducted a series of studies bearing on this issue. In his experiments, participants were given strings of letters to learn, such as the ones shown in Figure 8-3(A). Unknown to people in some of the experimental groups, the letters were not randomly chosen but were generated by a structure sharing similarities with certain kinds of language grammars.

Figure 8-3(B) depicts one such grammar. To generate a “legal” letter string—that is, in accord with the grammar—imagine yourself starting at the path marked “In” and moving to the path marked “Out,” following the directional arrows as you go. As you take each path, you add the letter of that path to your string. So the first letter of a “legal” string is always either a *T* or a *V*. Notice two loops in the grammar, one labeled *P* and one *X*. These loops can be followed any number of times (each time adding either a *P* or an *X* to the letter string), allowing letter strings that are infinitely long.

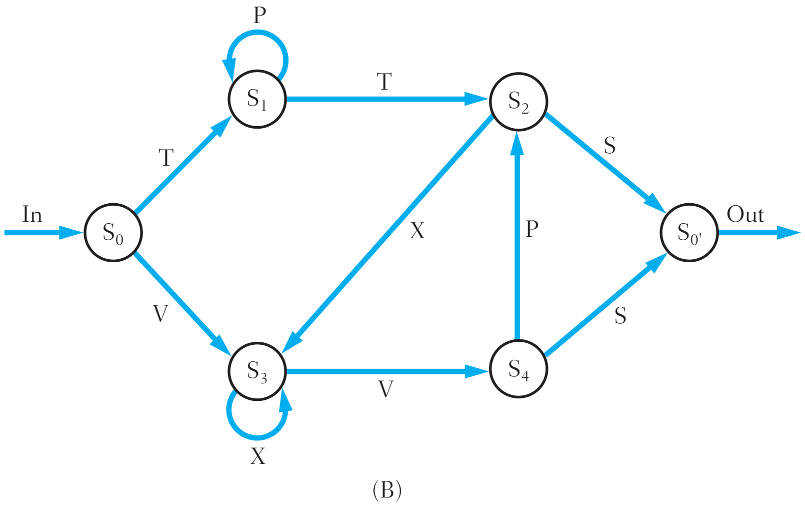
**FIGURE 8-3** ■ *Possible stimuli (A) and their underlying "grammar" (B) used by Reber (1967).*

**SOURCE:** Reber (1967, p. 856).

T P P T X V S      T T X X V S

V X X X V S      V X X V P S

(A)



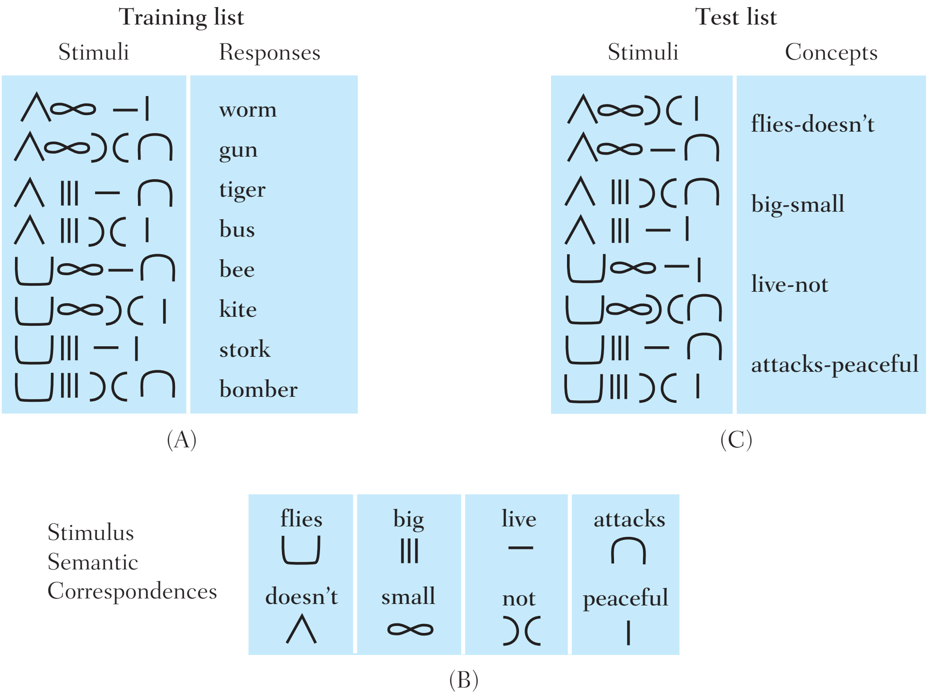
Reber (1967, 1976) found, first, that participants learning letter strings that followed the grammar made fewer errors than did control participants learning random letter strings. More surprising, participants who were told ahead of time that letter strings followed certain complex rules remembered strings less well than participants who were simply asked to memorize particular letter strings but were not told anything about the strings' following a structure. Reber concluded that when complex underlying structures exist (such as his grammar), people are better off memorizing exemplars than trying to figure out what the structure is, primarily because participants who try to guess the structure often induce or invent incorrect rules or structures.

Brooks (1978, 1987) believed that the processes Reber (1967) discovered are at work much of the time in ordinary cognition. Brooks called these processes **nonanalytic concept formation,** in contrast to analytic (logical, scientific, focused) concept formation such as exhibited by research participants in the Bruner et al. (1956) study. Nonanalytic concept formation, also sometimes called **implicit learning,** requires that people pay attention to individual exemplars, storing information about and representations of them in memory. Later classification is done by comparing new instances to the representations, drawing analogies between new and old.

In one study, Brooks (1978) had participants perform a paired-associates learning task, learning to associate hieroglyphic symbol strings with English words. Figure 8-4(A) presents examples of his stimuli. Each symbol in the string had a certain meaning, as shown in Figure 8-4(B), but participants were not alerted to this fact. Later they were unexpectedly given new strings, such as those in Figure 8-4(C), and were asked four questions: Does it fly? Is it big? Is it alive? Does it attack? Most of the participants reported they answered the questions by thinking of a previous example that looked similar. However, they generally couldn't point to any particular symbol in the string as a basis for their response.

**FIGURE 8-4** ■ *Stimuli from Brooks's (1978) experiments.*

**SOURCE:** Brooks (1978).


Training list
Stimuli
Responses
worm
gun
tiger
bus
bee
kite
stork
bomber
(A)
Test list
Stimuli
Concepts
flies-doesn't
big-small
live-not
attacks-peaceful
(C)
Stimulus Semantic Correspondences
flies
big
live
attacks
doesn't
small
not
peaceful
(B)

Brooks's results pose a puzzle for cognitive psychologists. Apparently, participants sometimes explicitly test specific hypotheses when forming concepts (as in the Bruner et al., 1956, experiments), sometimes they form prototypes (as in the Posner & Keele, 1968, experiments), and sometimes they memorize exemplars (as in the Reber, 1967, 1976, and Brooks, 1978, experiments). The question is, When and why do people adopt such different approaches?

Brooks (1978) believed the answer had to do with the concept formation task itself. Some simple laboratory tasks, such as the one used by Bruner et al. (1956), seem to lead participants to adopt an analytical, hypothesis-testing framework. Other, more complex stimuli lead people to abandon this approach for another. Brooks went on to describe five factors that encourage people to store information about individual exemplars.

The first factor involves task requirements to learn information that distinguishes among individual instances. Brooks (1978) reminded us that in natural situations, different items in the same category must sometimes be treated differently. It is all very well to recognize that Rover, the lovable family mutt, and Killer, the attack dog for the company down the street, are both dogs, but the child or adult who treats them as interchangeable could be in for a painful surprise.

A second factor involves the original learning situation. In many real-life situations, instances are not presented one at a time in rapid succession (as in many laboratory experiments). Instead, the same instance (Rover, the family mutt) may appear repeatedly (especially at mealtimes!), affording the person a chance to get to know certain instances very well.

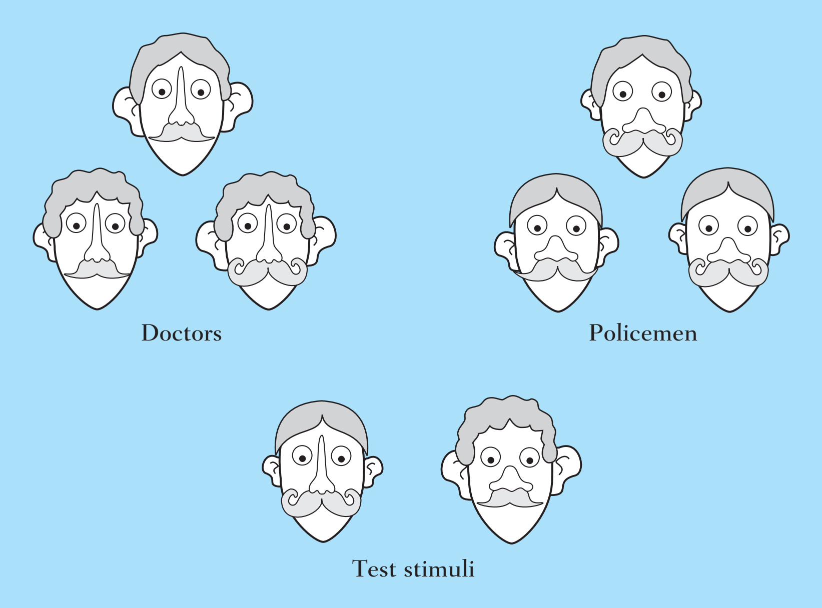
Third, some stimuli lend themselves to hypothesis testing better than others do. Notice that in the Bruner et al. (1956) stimuli, instances varied on only four dimensions. In real life, things vary in many complicated ways. Often, the relevant dimensions of variation are not apparent to the novice, an idea we discussed in the section on perceptual learning. A fourth factor is that in real-life concept learning, instances may belong to a number of categories all at the same time. Rover might belong to any of the following categories: “dog,” “family pet,” “partner to take to obedience classes,” “source of mud on rainy days,” or even “incurrer of large food bills.” Finally, Brooks pointed out that in natural settings, we learn about instances without knowing how we will be called on to use the information later.

Kemler Nelson (1984) also argued that much of our real-life conceptual knowledge is acquired nonanalytically rather than analytically. Her research has shown that children are especially likely to use this mode of concept learning, as are adults when they are not allowed to devote many cognitive resources to the task—for example, when they are forced to process information more rapidly than they might otherwise do (Smith & Kemler, 1984).

Furthermore, Kemler Nelson (1984) believed that nonanalytic concept formation is especially likely with materials that have strong family resemblance structures. Participants in one of her experiments were presented with artificial faces, such as those in Figure 8-5. The faces varied on four attributes—curliness of hair, length of nose, size of ears, and breadth of mustache—with each attribute having three values (such as slightly curly mustache, medium curly mustache, and very curly mustache). Participants learned which faces belonged to the category “doctors” and which to the category “policemen.” Faces presented

**FIGURE 8-5** ■ *Stimuli used by Kemler Nelson (1984).*

**SOURCE:** Kemler Nelson (1984, p. 742).



during the learning phase were carefully chosen, such that one attribute distinguished between the two categories (in this example, length of nose: Doctors have long noses; policemen, short ones). At the same time, the two categories differed in their family resemblance structure, although the difference was not absolute. In this example, doctors tend to have slightly curly mustaches, large ears, and broad mustaches, and policemen, very curly mustaches, small ears, and thinner mustaches, although not every instance shared all these features.

In the subsequent test phase, participants were presented with a number of test faces, including two "critical" test faces, and were asked to classify each one. These faces pitted the criterion feature (such as length of nose) against the family resemblance structure. The way people classified these faces revealed the basis of their classification: If they used a criterion feature, they classified the faces one way; if they used family resemblance structure, they were more likely to make a different classification. In this example (see Figure 8-5 again), note that the left test face has a long nose, suggesting it belongs to the "doctor" category, but that it has more overall similarity to faces in the "policemen" category; the reverse is true for the right face.

Some of Kemler Nelson's (1984) participants were explicitly told to search for a means of distinguishing between doctors and policemen; others were simply asked to learn to recognize the pictures. Kemler Nelson found the latter group was especially likely to use family resemblance structure as a basis for classification; approximately 60% did so. Of those in the former group, only 46% used that approach. She concluded that both the kinds of concepts being learned and the instructions about the task influence the concept acquisition strategy that people adopt.

## Using and Forming Scripts

In Chapter 7, we discussed the concept of scripts, schemata for routine events. If you and each of your classmates listed your knowledge of what happens when you purchase a meal at McDonald's, all the lists would likely show a very high level of agreement, in terms of what events and actions you mention, the order in which you mention them, and the level of description you use. My "McDonald's script" (well practiced of late because my four-year-old daughter loves Happy Meals) is roughly as follows: You enter; walk to the counter; wait in line; order food; pay the counterperson; wait while your order is assembled; carry the tray of food to the counter that holds napkins, straws, and ketchup; gather those supplies; find a table; sit and eat; gather the trash onto the tray; take the tray to the trash bin; dump the contents of the tray into the trash bin; leave. There are some personal variations to my McDonald's script, of course (for instance, checking the toy that comes with my daughter's Happy Meal and asking to exchange it if it's one she already has), but for the most part, I would bet my script overlaps with yours a great deal. Notice I don't specify details at the level of how many steps I need to walk or whether I turn right or left—these details vary at different McDonald's locations and don't much affect the script. The point is, my McDonald's script would work at your McDonald's, and vice versa.

Bower, Black, and Turner (1979) investigated how much people typically use scripts. They first asked participants to write their scripts for a number of specific events: going to a restaurant, attending a lecture, getting up in the morning, grocery shopping, visiting a doctor. They compared the notes generated by all the participants and found a high degree of overlap in what people mentioned. The participants generally agreed about which characters to describe, which props and actions to mention, and the order in which different actions would occur.

The investigators also found a high degree of agreement in description level. Thus most people would mention "eating the food" instead of "picking up a spoon, dipping it into soup, raising the spoon to lips, and sipping." In another study, Bower et al. (1979) showed that if information from a story was presented in scrambled order, people tended to recall it in the scripted order. In a further experiment, the investigators presented stories that mentioned only some of the events in a typical script. They found that in a later recall task, people often "recalled" information that wasn't in the story but was in the relevant script. Rizzella and O'Brien (2002) found that when people were given a narrative text to read and remember, central concepts relevant to the script (such as in a restaurant script, being served a meal) were typically better remembered than concepts of less importance to the script (such as giving one's name to a hostess).

## Psychological Essentialism

A proposal by Medin (1989), drawing on work by the philosopher Hilary Putnam (1975), has examined people's reliance on underlying nature as a basis for many concepts. Medin proposed a framework he called **psychological essentialism** and described several assumptions. The first is that people generally act as if objects, people, or events have certain essences or underlying natures that make them what they are. Presumably, for instance, a human being is a human being by virtue of having a certain molecular structure. That essence constrains or limits the kinds of variation that different instances of a category can show. So, for instance, people can vary in height, weight, hair color, eye color, bone structure, and the like, but they must have certain other properties in common by virtue of the underlying essence they share. People's theories about the essences of various categories help them connect deeper properties (such as the structure of DNA) to more superficial properties (such as eye color or hair color). For example, Medin pointed out that although most of us believe that the categories "male" and "female" are genetically determined, most of us look at characteristics such as hair length, facial hair, and so on, rather than conducting genetic tests when classifying a new person as a woman or a man. We may make errors in using superficial characteristics, but we probably won't often be led astray.

People's knowledge of the essence of a category varies by level of expertise. Biologists, in general, know a lot more about the genetic structure of a human being than do laypeople. For this reason, experts can generally be expected to make different and more accurate classifications, especially if the criteria for the classifications are subtle. Medin's (1989) idea is that classifying on the basis of perceptual or other superficial similarity may be a strategy that can be pretty effective much of the time. Still, when the situation calls for it and if the expertise is possessed, people classify on the basis of deeper principles. This suggestion implies, then, that people's classification of instances will change as they become more experienced and knowledgeable—an idea that fits well with our discussion of perceptual learning, as well as with the currently available data.

The way people acquire and mentally represent concepts may also vary as a function of what the concepts are (Murphy, 2005). Some psychologists have adopted the perspective of philosophers in distinguishing among kinds of concepts. **Nominal-kind concepts** include concepts that have clear definitions. **Natural-kind concepts,** such as "gold" or "tiger," are of things naturally occurring in some environment (Putnam, 1975). A third kind of concept is **artifact concepts,** things constructed to serve some function or accomplish some task (see Keil, 1989; Schwartz, 1978, 1979, 1980). Different information may be represented in different kinds of concepts.

For instance, nominal-kind concepts (such as the ones Bruner taught participants in his studies) may include information about necessary and sufficient features, because these things exist as part of the concept definition. Natural-kind concepts may include more information about definitional or essential features, especially about molecular or chromosomal structure. Natural-kind concepts may also be more likely to have a family resemblance structure but can be equally well explained within a knowledge-based approach.

Artifact concepts, in contrast, may highlight information about the object's purpose or function and may be adequately described only within the knowledge-based approach. In one study, Barton and Komatsu (1989) presented participants with five natural-kind concepts (such as *goat, water, gold*) and five artifacts (such as *TV, pencil, mirror*). With each concept, they asked the participants to imagine different transformations. Some transformations were phrased in terms of function or purpose (for example, a female goat that did not give milk or a TV with no visible picture); others were in terms of physical features (for example, gold that was red in color or a pencil that was not cylindrical). A third type of change was molecular (for example, water that did not consist of the formula $H_2O$, or a mirror not made out of glass). The investigators found that with natural-kind terms participants were most sensitive to molecular transformations, whereas with artifact terms they were most sensitive to functional changes. Apparently, then, all concepts are not treated equally, and, under at least some conditions, people use their knowledge about why instances of a category should be grouped together in their representation of the related concept (Medin, Lynch, & Solomon, 2000).

## SUMMARY

1. Categories are classes of similar objects, events, or patterns. Concepts are mental representations of those categories. Concepts are thought to help us order our knowledge and to relate new objects or patterns to previously encountered ones.
2. There are five distinct approaches to the study of concepts. These have been themselves categorized into two major types: similarity-based and explanation-based (Komatsu, 1992).

3. The similarity-based category, comprising the classical, prototype, and exemplar views (and some parts of the schemata view), includes the approaches in which categorization is assumed to be based on the similarity of an instance to some abstract specification of the category (for example, a definition or a prototype) or to one or more stored exemplars.
4. The explanation-based category, comprising aspects of the schemata/scripts view and aspects of the knowledge-based view, instead sees people as classifying instances based on meaningful relationships among instances and categories.
5. The classical approach to concepts posits that each concept is defined by a set of necessary and sufficient features.
6. The prototype approach to concepts holds that we categorize objects by comparing them to mental abstractions, called prototypes, which are idealized representations of some class of objects or events.
7. The exemplar approach to concepts assumes we store specific individual instances and use these stored representations to categorize.
8. The schemata/scripts view regards concepts as schemata, packets of information with specific parts, that fill in default values for aspects of the situation.
9. Proponents of the knowledge-based view of concepts hold that people use their own theories to guide their classification of objects.
10. When people are explicitly asked to form concepts and to search for underlying rules or features, they seem to acquire and use different kinds of information from what they use when left to their own exploration. This raises the question of applicability of very traditional laboratory-based investigations of concept formation to the processes people use outside the laboratory. What gets learned depends, apparently, on the original learning materials, the task instructions, and the learner's anticipation of how the learned information will be used in the future. As in other areas of cognition, then, the way people process information is flexible and varies with the situation and the purpose of the task.

## REVIEW QUESTIONS

1. Describe the distinction many cognitive psychologists make between concepts and categories. What are the cognitive benefits of having concepts? Explain.
2. Contrast the classical, prototype, and exemplar proposals for how concepts are mentally represented. What kinds of arguments and/or empirical findings support each? What kinds of arguments and/or empirical data are troublesome for each?

3. Describe what a family resemblance structure is and how it relates to the prototype approach to concepts.
4. Compare and contrast the schemata view and the knowledge-based view of concepts. Are the two compatible? How or how not?
5. Briefly review Reber's work on implicit learning and its implications for concept formation.
6. Give some new examples of scripts, and justify your examples.
7. Discuss this statement: "Any approach to concepts must strike some balance between cognitive economy and informativeness."

## KEY TERMS

artifact concept
basic level of categorization
category
classical view of concepts
concept
exemplar view of concepts
family resemblance structure of concepts
features
implicit learning
knowledge-based view of concepts
natural-kind concept
nominal-kind concept
nonanalytic concept formation
prototype
prototype view of concepts
psychological essentialism
schemata/scripts view of concepts
subordinate level of categories
superordinate level of categories

## CogLab DEMONSTRATIONS

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

The **Prototypes** demonstration provides you with an experience similar to those of research participants in Posner and Keele's classic dot-pattern categorization study.

## WEB RESOURCES

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

## CHAPTER 9

# Visual Imagery and Spatial Cognition

**Mnemonics and Memory Codes**
- Mnemonics
- The Dual-Coding Hypothesis
- The Relational-Organizational Hypothesis

**Empirical Investigations of Imagery**
- Mental Rotation of Images
- Scanning Images

**The Nature of Mental Imagery**
- Principles of Visual Imagery
- Critiques of Mental Imagery Research and Theory

**Neuropsychological Findings**

**Spatial Cognition**

Think of the house or apartment you consider your permanent residence. In particular, think about its kitchen. How many cabinet doors does it have? Obviously, this question draws on your memory. Most people can answer it after some mental work. What sort of work is required? In the process I used, I first recognized that I didn't have the information needed already stored; that is, I didn't know the answer "off the top of my head." So I had to determine the answer in another way. I mentally pictured my kitchen by drawing on memory. Then, starting at one end of the room, I scanned my mental picture, counting cabinet doors. My procedure is neither difficult nor original (Shepard, 1966) but seems to be the one commonly used.

The nature of these "mental pictures," or **visual images,** is the focus of this chapter. We will look at the role of images in memory and at how images are used in techniques called *mnemonics,* which are designed to aid or improve memory. We will also consider experiments investigating the ways in which people construct and use visual images and what these findings suggest about cognition. Finally, we will turn to the nature of visual images, considering the kinds of mental representations used to create and store them.

Throughout the chapter, we will confine ourselves to discussion of visual images. Recognize, however, that other kinds of mental images exist. Examples include auditory images (such as the imagined sound of your dog barking), olfactory images (such as the imagined smell of fresh-baked bread), and cutaneous images (such as the imagined feeling of your toe being stubbed into the wall). Visual images, like visual perception, have received the most attention within cognitive psychology. Thus, as we did in examining perception (Chapter 3), where we focused on visual perception, in this chapter we will focus on visual imagery.

The study of visual imagery has had a controversial history within psychology (Paivio, 1971). Although occasional references to imagery were made at the turn of the 20th century, the rise of behaviorism essentially dictated that even the concept of an image be rejected. Visual images are problematic as objects of scientific inquiry. After all, the experience of a visual image is just about as private an experience as one can have. If I assert that I am forming a visual image of my kitchen, no one but I can tell if I really have the image or am just pretending. Visual images, unlike behaviors, cannot be seen, counted, or controlled by other people. Because visual images can be reported only by the person who asserts she is experiencing them, that person can distort or bias them, either consciously or inadvertently. Behaviorists argue that imagery is not the sort of topic that can be investigated with sufficient scientific rigor or control.

Nonetheless, interest in visual imagery never completely vanished (Paivio, 1971) and in fact became stronger after the popularity of behaviorism waned in the 1960s. It is difficult to explain how people perform certain cognitive tasks, such as the one described earlier, without talking about visual images. Moreover, research on memory suggests that people who report using imagery are better able to recall information than people who do not.

Sports psychologists, too, have a strong interest in the use of visual imagery. An athlete who before competing spends time mentally imagining a smoothly executed, well-timed, elegant performance has been shown to perform better a bit later when engaging in her or his sport (Martin, Moritz, & Hall, 1999). Very recent research suggests further that imagery can be used to help people cope with negative emotional events, such as remembering a real incident of being rejected, abandoned, or excluded. Research participants asked to visualize so-called "cool" aspects of the experience—for example, where they were standing or sitting in relation to other people during the incident—were better able to reduce their hostile feelings than were participants asked to image their visceral reactions during the incident, or participants not asked to form any images (Ayduk, Mischel, & Downey, 2002).

Psychologists now recognize that to eliminate imagery as a subject of discussion and investigation is to overlook a potentially fundamental aspect of cognition. Hence visual imagery has regained credibility as a worthwhile topic among most cognitive psychologists.

## ■ MNEMONICS AND MEMORY CODES

If you want to increase your chances of remembering (and especially recalling) information, you can make use of several techniques, collectively called **mnemonics.** We will see that many (although not all) involve the construction of mental pictures or images. We'll begin by looking at a number of the best-known mnemonics, examining two theoretical explanations for why they work.

### Mnemonics

Around 500 B.C., the Greek poet Simonides was called out from entertaining diners at a banquet. While he was out of the hall, the roof caved in, crushing the guests so badly that they could not be identified by members of their families. Simonides, by recalling where each guest sat, was able to help relatives find the remains of their family members (Paivio, 1971). Thus was invented one of the first mnemonic techniques, often called the **method of loci.**

The method of loci, as the name might suggest, requires the learner to imagine a series of places (locations) that have some sort of order to them. For example, I might use a series of landmarks I pass on my way from my office to the campus snack bar. I would then divide the material I wanted to remember, mentally picturing the different pieces at the different landmarks.

Suppose that I needed to remember to bring certain things to a meeting—for example, a tablet, a pen, certain computer printouts, a book, and a calculator. I could use the method of loci to remember these materials in the following way. First, I would imagine myself walking through my office doorway (first locus) and propping the first object (the tablet) against the door as a doorstop. Next I would see myself walking by my secretary's desk, leaving my pen on the desk atop a letter or note. Then I would see myself walking into the hall and down the nearby stairwell, draping the printouts over the railing at the top of the stairs. I would mentally exit the building, pass a big oak tree to my left, and place the book on one of its branches. Finally, as I entered the student union, I would picture the calculator hung from the front door. When I needed to remember these five items, all I would need to do would be to mentally "take a walk" over the same route, noticing the objects I passed. Essentially, I would take the same path again, this time looking around in my image as I did so.

### Box 9-1 Principles of Use of the Method of Loci

1. Use a list of cues that you know well. You can't retrieve any associations if the cue images aren't available at both presentation and recall.
2. The cues must be memory images of geographic locations.
3. Associations must be formed between the items to be remembered and the cue locations at the time you originally encounter the items.
4. The associations between cue locations and the items must be one to one.
5. Use imagery, especially visual imagery, to form associative links.
6. Use interactive images to link the item and its cue location.
7. If you study the items more than once, the same cue location should be used for a given memory item.
8. During recall, cue your own memory by using the list of locations.
9. Use the same recall cues (locations) that you used during study.

**SOURCE:** Adapted from Bower (1970a).

Bower (1970a) provided a list of principles that improve the workings of the method-of-loci technique (see Box 9-1). Figure 9-1 shows how the method of loci might work in remembering items from a shopping list. Ross and Lawrence (1968) showed that college students trained in using the method of loci could recall up to 38 of 40 words after one presentation; by any standard, this level of performance is exceptional.

Another technique for improving memory could be called the technique of *interacting images.* A study reported in 1894 anticipated the usefulness of this technique. The results indicated that recall of concrete nouns on a list improved when participants were told to form images of the words, in comparison to when they were not given such instructions (Kirkpatrick, 1894). Bower (1970b) found similar results in experiments of paired-associates learning (review Chapter 6 if you've forgotten what this is). In other words, if participants were given pairs of words such as *goat–pipe,* participants who formed images of, say, a goat smoking a pipe recalled almost twice as many paired associates as control participants who were not instructed to use imagery. These figures may underestimate the effect, because some control participants may have spontaneously used imagery.

Bower's (1970b) research showed in particular that for images to be maximally effective in paired associates, participants should try to form images that interact—for example, a goat *smoking* a pipe rather than simply a picture of a goat next to a picture of a pipe, with the two pictures separated in space. The principle of interactive imagery applies equally to the method-of-loci technique: The images should depict the to-be-remembered items interacting in some way with items at the various loci (see Principle 6 in Box 9-1). Notice that in

**FIGURE 9-1** ■ *Illustration of the method of loci. Items to be remembered: hot dogs, cat food, tomatoes, bananas, whiskey. Locations: driveway, garage, front door, closet, kitchen sink.*

**SOURCE:** Bower (1970a, pp. 497–499).

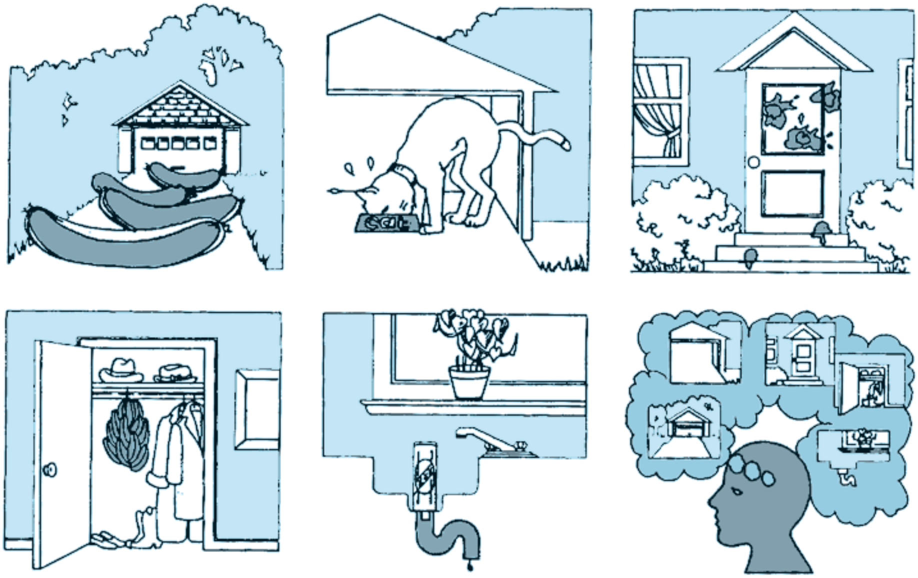


Figure 9-1, which depicts the use of the method of loci, all the images involve interaction between the to-be-remembered items and other aspects of the different locations.

A third mnemonic technique, one that also involves imagery, is called the *pegword method*. Like the method of loci, it involves picturing the items with another set of ordered "cues"—pegging them to the cue. In this case, the cues are not locations but rather nouns that come from a memorized rhyming list: "One is a bun, two is a shoe, three is a tree, four is a door, five is a hive, six is sticks, seven is heaven, eight is a gate, nine is wine, and ten is a hen." The method calls for the participant to picture the first item interacting with a bun, the second with a shoe, the third with a tree, and so forth (notice that the method works for lists of only 10 items or fewer). Bugelski, Kidd, and Segmen (1968) showed that the method also improves recall in paired-associates tasks as long as participants are given 4 seconds or more per item to form the images.

Not all mnemonic techniques have to do with imagery. One set of techniques that does not involve visual imagery per se involves *recoding* the material to be recalled, adding extra words or sentences to *mediate,* or go between, your memory and the material. One example, familiar to most schoolchildren, involves taking the first letter of each word you want to remember and forming a word or sentence from these letters. This technique can be used to recall the names of the Great Lakes (*HOMES:* Huron, Ontario, Michigan, Erie, Superior) or to recall the names of the notes on the lines of a musical staff ("Every good boy deserves fudge"). Research investigating the usefulness of this technique reports mixed results, although the technique is popular (Carlson, Zimmer, & Glover, 1981). Notice, by the way, that the words and sentences serve functions similar to those of the images in the techniques described previously. Both are *mediators:* internal codes that connect the items to be remembered and your (later) overt responses (Klatzky, 1980).

Finally, as mentioned in Chapter 6, various types of categorization and organization of material also improve recall. Arranging material into categories helps organize the material, and this in turn raises its probability of recall. As discussed in Chapter 6, organization presumably adds to the number of "hooks" attached to the material to be remembered, and the greater the number of hooks, the greater the probability of recall.

Why do so many mnemonic techniques use visual imagery? How do imagery-based mnemonics function differently from non-imagery-based mnemonics? Does something about visual images per se make them especially memorable? We will consider two opposing views on this matter.

## The Dual-Coding Hypothesis

Allan Paivio (1969, 1971, 1983) originated the **dual-coding hypothesis** of memory to explain the workings of various mnemonics. According to Paivio, long-term memory contains two distinct coding systems (or codes) for representing information to be stored. One is verbal, containing information about an item's abstract, linguistic meaning. The other involves imagery: mental pictures of some sort that represent what the item looks like. Items to remember can be coded by either verbal labels or visual images and in some cases both. Paivio's idea is that pictures and concrete words give rise to both verbal labels and visual images; that is, they have two possible internal codes or mental representations. Abstract words, in contrast, typically have only one kind of code or representation: a verbal label.

One study by Paivio (1965) provided evidence to support this hypothesis. Participants were asked to learn one of four lists of noun pairs. The first list (CC) included pairs in which both referred to concrete objects (for example, *book–table*). The second list (CA) included pairs in which the first noun was concrete and the second abstract (such as *chair–justice*). The third list (AC) was the converse of the second (such as *freedom–dress*). The fourth (AA) contained pairs of abstract nouns (for example, *beauty–truth*). Of a possible 16 correct responses, participants averaged 11.41, 10.01, 7.36, and 6.05 correct responses for the CC, CA, AC, and AA lists, respectively.

Paivio (1965) explained the results as follows. Whenever possible, participants spontaneously formed visual images of the noun pairs. The formation was easiest with concrete nouns. Paivio (1969) assumed that visual imagery, unlike verbal labeling, increases as a function of concreteness: the more concrete the noun, the richer the image and the more elaborated the internal code. This helps explain why pictures (very concrete) are often remembered better than words (see, for example, Kirkpatrick, 1894; Shepard, 1967). When items are coded by both images and verbal labels (as concrete nouns can be), the chances of the learner's retrieving them are obviously better. If the learner forgets the verbal label, he or she might still access the visual image, or vice versa. Items coded only by verbal labels are disadvantaged; if the verbal label is forgotten or "misplaced," the learner has less to go on.

Further, Paivio (1969) believed that the first noun in a pair (called the "stimulus" noun) serves as a *conceptual peg* on which the second ("response") noun is hooked. In this sense, the stimulus noun serves as a "mental anchor," a place to which the representation of the response noun can be attached. Thus the imaginability of the first noun is particularly important in improving memorability, explaining why recall in the CA condition was significantly higher than in the AC condition.

## The Relational-Organizational Hypothesis

Bower (1970b) proposed an alternative to the dual-coding hypothesis that he called the **relational-organizational hypothesis.** He believed that imagery improved memory not because images are necessarily richer than verbal labels, but because imagery produces more associations between the items to be recalled. Forming an image (say, between two words in a pair, or between a word and a location, as in the method of loci) typically requires the person to create a number of links or hooks between the information to be remembered and other information. Recall from Chapter 6 that the more "hooks" a piece of information in memory has to other information, the greater are the chances of recalling it. Bower's argument, then, is that imagery works by facilitating the creation of a greater number of hooks that link the two to-be-remembered pieces of information.

Bower (1970b) performed an experiment to distinguish between the dual-coding and the relational-organizational hypotheses. Participants were divided into three groups, each given different instructions for a paired-associates learning task. One group was told to use "overt rote repetition" (that is, to rehearse aloud); the second, to construct two images that did not interact and were "separated in imaginal space"; the third, to construct an interactive scene of the two words in a pair (p. 530). Results showed that all participants recognized about 85% of the previously seen words. However, recall of those words differed greatly. Those who used rote memorization recalled about 30% of the paired associates; those using noninteractive imagery, 27%; and those who formed interacting images, about 53%.

If imagery simply led to more elaborated coding of the paired associates, as the dual-coding hypothesis predicts, then participants in the two conditions that involved instructions to form two images ought to have performed similarly. In fact, only those who formed interacting images showed an improvement over the rote memorizers. Apparently, it is not imagery per se that helps memory but rather the way in which imagery is used. Interacting images presumably create or suggest more links between the target information and other information, making the target information easier to retrieve.

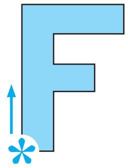
Although the dual-coding hypothesis continues to attract proponents (see Yuille, 1983), still unresolved are how well it explains the workings of imagery mnemonics and what kind of explanations it provides for nonimagery mnemonics. However imagery mnemonics work, there is at least little doubt that many do aid memory. To understand how these mnemonics work, it will be necessary to explore further what imagery is and how it works, topics we turn to next.

## EMPIRICAL INVESTIGATIONS OF IMAGERY

A series of studies by Lee Brooks (1968) is widely regarded as yielding some of the best evidence that images are distinct from verbal materials or at least use different processes from those used by verbal materials. Figure 9-2 depicts different conditions of Brooks's primary experiment. In one condition, participants were asked to imagine a letter, such as the outlined capital *F* in Figure 9-2(A), and then to move clockwise mentally from a particular corner (marked in

**FIGURE 9-2** ■ *Stimuli from the Brooks (1968) study.*

**SOURCE:** Brooks (1968, pp. 350–351).



A BIRD IN THE HAND IS NOT IN THE BUSH.

Start at the corner marked with an asterisk, and indicate whether or not each corner is at the extreme top or bottom.

(A)

For each word in the sentence above, indicate whether or not each word is a noun.

(B)

Figure 9-2 with an asterisk) and to indicate, for each corner, whether it was at the extreme top or extreme bottom of the letter. In this example, the correct responses are "yes, yes, yes, no, no, no, no, no, no, yes."

Participants indicated their responses in different ways. One mode of response was verbal: Participants said "yes" or "no," as noted. Another response mode was spatial. Participants were given a response sheet on which the letters *Y* and *N* were printed in an irregular pattern and were told to point to either a *Y* or an *N* in each row to indicate their responses. Brooks (1968) found that participants took almost two and a half times longer when they responded by pointing than they did by responding verbally.

On a second task, Figure 9-2(B), participants were asked to remember a sentence, such as "A bird in the hand is not in the bush," and, for each word, to indicate whether it was a concrete noun. In this example, the correct responses are "no, yes, no, no, yes, no, no, no, no, yes." As with the previous task, sometimes participants responded verbally, and other times they pointed to *Y* or *N* on a response sheet. With this task, however, people were faster to respond by pointing than they were to respond verbally (although the difference in response times was not as great).

One explanation for these results is as follows. The first task requires the formation of a visual image of an *F.* The visual image probably has at least some picturelike qualities (spatial or visual), so a spatial or visually guided response (pointing) would be interfered with to a greater extent than would a verbal response. In other words, the visual image is more disruptive of, and disrupted by, another spatial or visual type of task (pointing) than by a verbal kind of task (talking). The converse is also true: Holding a sentence in memory (a verbal task) is easier to do with a concurrent visual/spatial task (such as pointing) than with another verbal task. Notice that pointing or talking do not differ in difficulty overall but vary in difficulty as a function of the task with which they are being performed. Brooks's (1968) work supports the idea that images and words use different kinds of internal codes (as the dual-coding hypothesis suggests).

Brooks's (1968) task is not the only one that apparently requires people to form visual images. Here is another. Answer the following question: Which is larger, a pineapple or a coconut? (Finke, 1989). To answer the question, you most likely constructed a visual image of a coconut next to a pineapple and "read" the answer from your image.

Moyer (1973) asked similar questions and found that people were faster to respond when the two objects (in his study, animals) differed greatly. This effect, called the *symbolic-distance effect,* works as follows. Other things being equal, you'd be faster to answer the question "Which is bigger, a whale or a cockroach?" than the question "Which is bigger, a hog or a cat?" Interestingly, the same pattern of response times is also obtained when people look at actual objects (Paivio, 1975). In other words, you'd be faster to answer the first question even if, instead of consulting visual images, you looked at the actual animals or at photographs of the animals. This result suggests that images seem to function, at least in some ways, like pictures. If people merely retrieved verbal information (for example, from a semantic network such as those described in Chapter 7), it would be difficult to explain this pattern of results.

## Mental Rotation of Images

The preceding studies suggest that people create and use visual images to answer certain questions and perform certain tasks. They also suggest that the images created are in some ways picturelike (although this conclusion has been energetically debated, as we'll see). At the same time that these findings were reported, other studies showed that people could do more than simply create images; they could also, apparently, mentally transform them.

One of the most famous studies of this type was performed by Shepard and Metzler (1971). They showed participants perspective line drawings of three-dimensional objects (Figure 9-3 presents examples). On each trial, participants would see two drawings. In some cases, the two drawings depicted the same object but with one rotated by some degree. In the other cases, the drawings depicted mirror-image reversals; in other words, the objects were similar but not identical. The mirror images were also sometimes rotated. The kinds of rotations used were either in the picture plane (that is, as if the drawing were rotated on the page) or in depth (that is, as if the object were going toward or away from the viewer). Shepard and Metzler (1971) found that the amount of time it took participants to decide if the two drawings depicted the same object or a mirror-image reversal was directly proportional to the angle of rotation between the drawings.

**FIGURE 9-3** ■ *Stimuli from the Shepard and Metzler (1971) study.*

**SOURCE:** Shepard and Metzler (1971, p. 701).

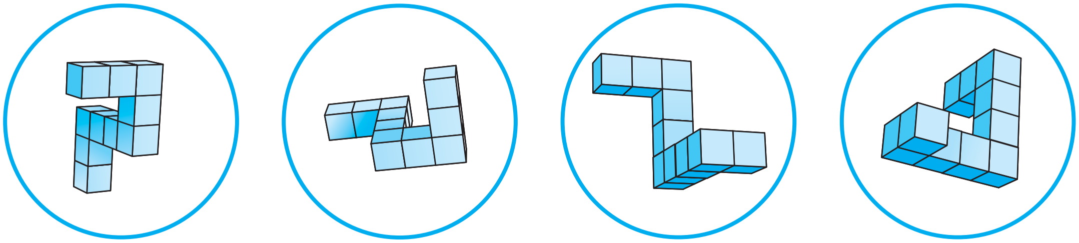


**FIGURE 9-4** ■ *Results from the Shepard and Metzler (1971) study.*

**SOURCE:** Shepard and Metzler (1971, p. 701).

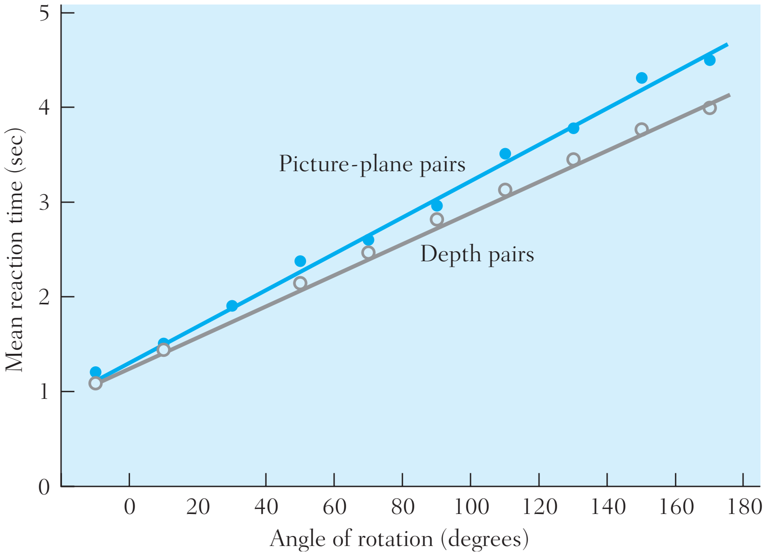


Figure 9-4 shows their results. This close correspondence between the angle of rotation of the two drawings and the participants' reaction times strongly suggests that they performed the task by **mental rotation** of one drawing. Moreover, the time it took participants to come to a decision was the same for rotations in the picture plane and in depth. This suggests they were mentally rotating three-dimensional images, not just the two-dimensional drawings. Had participants been rotating only the latter, their performance would have differed as a function of whether the rotation was in the picture plane or in depth.

Later studies by Cooper and Shepard (1973, 1975) showed that participants also mentally rotated more recognizable stimuli, such as alphabet letters or drawings of hands. In one study (Cooper & Shepard, 1973), participants were sometimes given a drawing of the letter to be used on a trial, followed by a cue showing the orientation to which the test stimulus would be rotated, before the test stimulus appeared. If these two cues were presented early enough (for example, 1,000 milliseconds before the test stimulus appeared), then the participants' performances were the same for all angles of rotation. Figure 9-5 depicts the experimental conditions, and Figure 9-6 shows the results.

Note the shape of the curves in Figure 9-6, which suggests that participants were able to mentally rotate their images either clockwise or counterclockwise, depending on which direction led to a lesser angle. These results differ from

**FIGURE 9-5** ■ *Cooper and Shepard's (1973) experimental design.*

**SOURCE:** Cooper and Shepard (1973, p. 247).

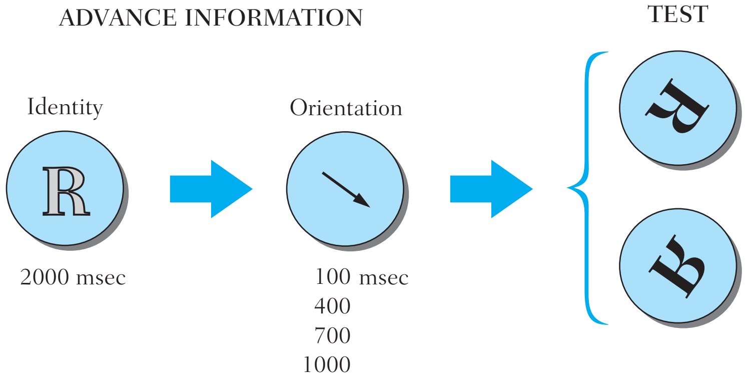
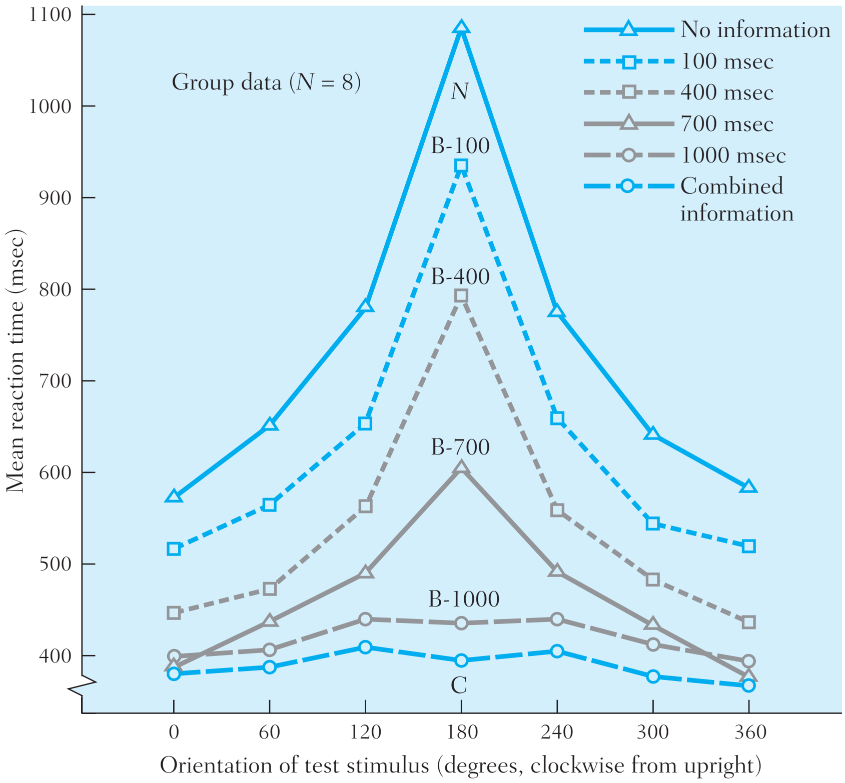

ADVANCE INFORMATION
TEST
Identity
R
2000 msec
Orientation
100 msec
400
700
1000

**FIGURE 9-6** ■ *Results from the Cooper and Shepard (1973) study.*

**SOURCE:** Cooper and Shepard (1973, p. 248).

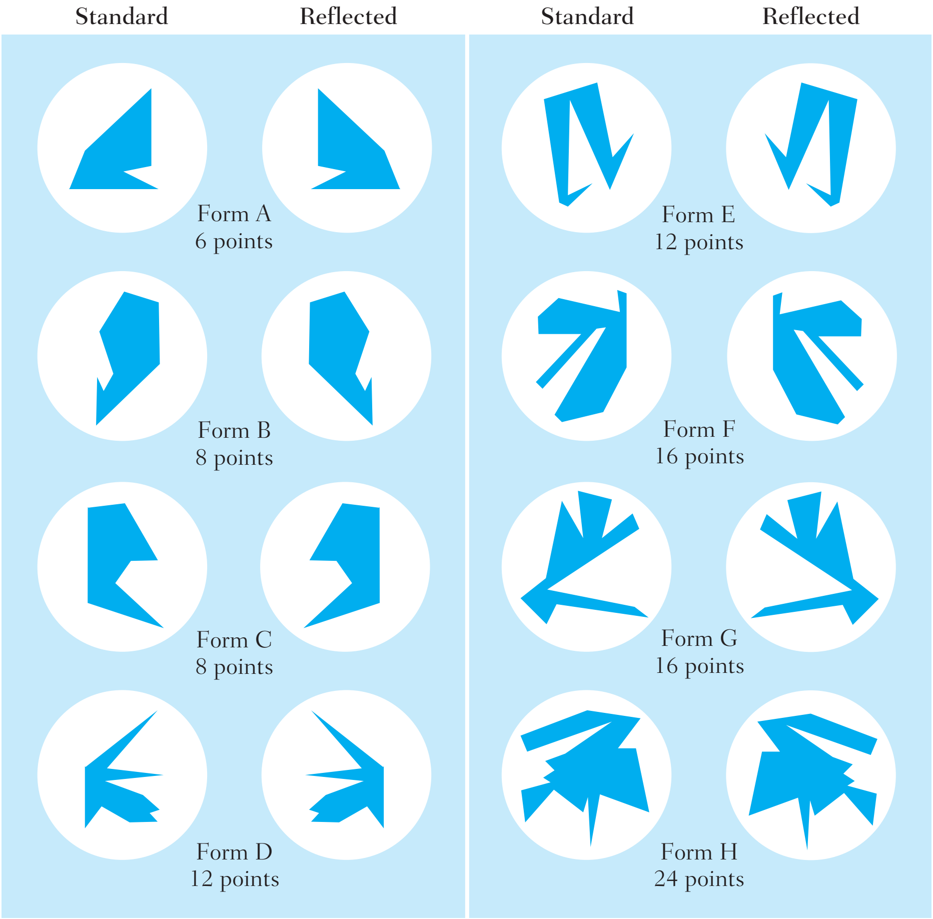


those of Shepard and Metzler (as a comparison of Figures 9-4 and 9-6 shows), presumably because alphanumeric characters have a known "upright" position, whereas Shepard and Metzler's line drawings do not. By the way, one reason for the "peaks" in reaction times at 180 degrees might be that participants were uncertain about which direction to rotate the figure, so that the uncertainty contributed to some hesitance.

Are participants in these experiments mentally rotating the whole stimulus, or are they looking only at certain parts? To answer this question, Lynn Cooper (1975) performed studies that presented participants with irregular polygons, such as those shown in Figure 9-7. The polygons were formed by connecting a

**FIGURE 9-7** ■ *Stimuli from the Cooper (1975) study.*

**SOURCE:** Cooper (1975, p. 23).


Standard
Reflected
Standard
Reflected
Form A
6 points
Form B
8 points
Form C
8 points
Form D
12 points
Form E
12 points
Form F
16 points
Form G
16 points
Form H
24 points

randomly scattered number of points, with more complex polygons resulting from a greater number of points. Participants were first trained to discriminate between original and mirror-image reflections of the polygons. Next, they were shown either the original polygons or the reflections at different angles of rotation and were asked to determine whether the object depicted was the original or a reflection of the original.

Cooper (1975) found that the reaction times once again increased linearly with the angle of rotation and that the rate of rotation was the same for all the polygons, regardless of their complexity. If participants were attending only to parts of the polygons, then performance ought to have differed as a function of the polygon complexity. Instead, it appears that participants mentally rotated entire polygons, treating the very simple polygons in exactly the same manner as they did the very complex ones.

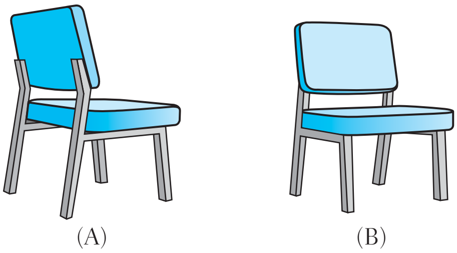
In another study, Cooper (1976) showed that mental rotations, like physical rotations, are continuous in nature. Her demonstration worked as follows. She determined, for each person, his or her rate of mental rotation. To do this, she showed participants a polygon at a particular orientation. The polygon was removed, and participants were asked to start mentally rotating it in a clockwise direction. As they were doing this, a test shape (the polygon or its mirror image reflection) was presented in some orientation. If the test shape was presented at the orientation corresponding to the orientation at which the participants' visual images would be expected to be, their reaction times were always fast. As the disparity between the actual orientation of the test shape and the expected orientation of the visual image grew, the reaction times to respond grew longer.

These results in particular suggest that mental rotation works like physical rotation. If you draw a shape on a piece of paper and slowly rotate the paper 180 degrees, the drawing will pass through intermediate orientations: 10 degrees, 20 degrees, and so on. Similarly, it appears from Cooper's (1976) work that rotating images pass through intermediate angles of orientation.

Since Cooper's landmark studies, other cognitive psychologists have studied whether and how people use mental rotation in recognizing objects presented at unusual angles. Consider, for example, the object(s) depicted in Figure 9-8(A) and (B). How do you recognize (A) as depicting the same object as (B)? One possibility is that you mentally rotate an image of (A) until it reaches some canonical, or standard, orientation of depiction, such as shown in (B). Tarr and Pinker (1989) and Gauthier and Tarr (1997a, 1997b) provided evidence of mental rotation in recognizing two-dimensional shapes drawn to resemble asymmetric characters. Biederman and Gerhardstein (1993), in contrast, argued that when people view three-dimensional objects (or line drawings of them), as long as the distinctive geons (the basic geometric components shown

**FIGURE 9-8** ■ *Two views of a chair. The pose depicted in (A) is a 90-degree clockwise rotation of the pose depicted in (B).*

**SOURCE:** Biederman and Gerhardstein (1993, p. 1163).



in Figure 3-10) of the object remain visible people can recognize the object without performing mental rotation. This debate is very much ongoing. However, notice that both sides of the debate employ concepts and models used to explain perceptual phenomena.

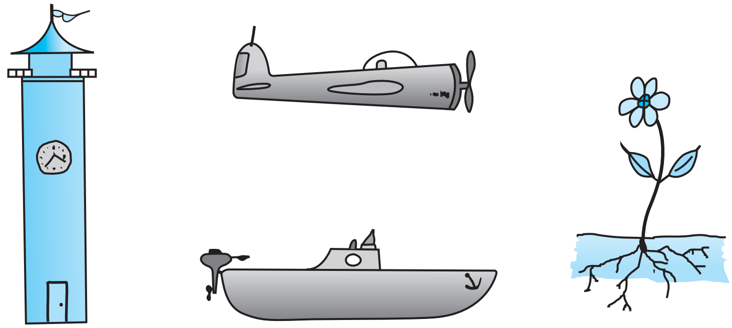
## Scanning Images

The research reviewed so far suggests that people can construct and transform their visual images. This evidence also seems to suggest that images are in many ways like pictures: They contain visual information, and the kinds of transformations performed on them seem to correspond to similar transformations on pictures. Another series of studies, carried out by Stephen Kosslyn, investigated the spatial properties of images. The series typically required participants first to form a visual image and then to scan it, moving from one location to another in their image, a process known as **imaginal scanning.** The idea is that the time people take to scan reveals something about the ways images represent spatial properties such as location and distance (Finke, 1989).

In one study, Kosslyn (1973) had participants study drawings of objects such as those shown in Figure 9-9. Notice that these drawings are elongated either vertically or horizontally and that each has three easily describable parts: two ends and the middle. After the initial learning phase, participants were told to form an image of one of the drawings and then to "look for" a particular part (for example, the petals of the flower). Some participants were told to focus first on one part of the image (for example, the top or the left) and then to scan, looking for the designated part. Kosslyn's results showed that the longer the distance from the designated end to the location of the part, the longer it took people to say whether the part they were looking for was in the drawing. So, for example, participants told to form an image of the flower and to start scanning

**FIGURE 9-9** ■ *Stimuli from the Kosslyn (1973) study.*

**SOURCE:** Kosslyn (1973, p. 91).



at the bottom took longer to "find" the petals (at the top of the drawing) than they did to "find" the leaves (in the middle of the drawing). Presumably, this is because the visual image formed preserves many of the spatial characteristics of the drawings: Parts of the drawings that are separated in space are also separated in the image.

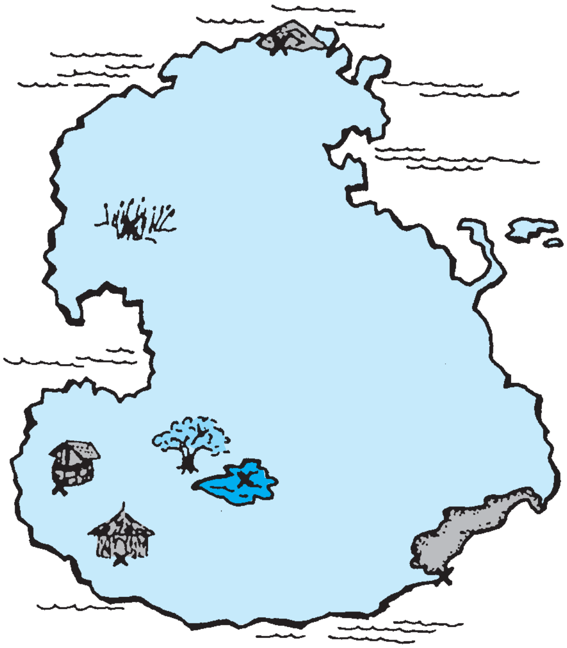
The results of the study were not entirely clear, however. Lea (1975), for instance, argued that perhaps the reaction times increased, not because of increased distance in the image, but because of the number of items in the image that had to be scanned. Notice, in the flower example, that if one started from the bottom, one would scan over the roots and the leaves on the way to the petals, but only over the roots to get to the leaves. Lea reported results supporting this interpretation.

In reply, Kosslyn, Ball, and Reiser (1978) performed another series of studies of image scanning. In one, they first created a map of a fictional island and had participants memorize the locations of seven objects shown on the map, reproduced in Figure 9-10. Notice that the seven objects allow for the construction of 21 distinct paths—for example, from the tree to the lake and from the tree to the hut. The paths vary in length, from 2 cm to 19 cm, and none contains any intervening objects.

Participants were instructed to focus mentally on one object. A few seconds later, the experimenter named another object on the island, and participants were then asked to imagine scanning to this second object by imagining a small black speck moving across the map in a straight line. They were instructed to push a button when they "arrived" at the second object, and their reaction times were recorded. The reaction times to scan between objects were correlated with the distance between objects (Kosslyn et al., 1978); that is, participants took more time to scan between two distant objects than they did to scan between two nearby ones. This reinforced the idea that images preserve spatial

**FIGURE 9-10** ■ *Stimuli from the Kosslyn et al. (1978) study.*

**SOURCE:** Kosslyn et al. (1978, p. 51).



relations. Related studies by Pinker (1980) showed similar results when the stimulus was a three-dimensional array of objects (toys suspended inside an open box).

Kosslyn's work suggests that people's scanning of their visual images is in some ways similar to their scanning of actual pictures: The greater the distance between two parts, the longer it takes to scan between them. Images apparently depict at least some spatial information, and people can retrieve this information from their images. These conclusions have strengthened the metaphor of images as kinds of "mental pictures" (Kosslyn, 1980).

Adding some interesting wrinkles to Kosslyn's conclusions, however, is work by Barbara Tversky (1981) on people's systematic errors in memory for maps. Before reading further, close this book, draw a map of the United States, and put in it the following cities: Seattle; Portland, Oregon; Reno; Los Angeles; San Diego; Chicago; Boston; Portland, Maine; Philadelphia; New York; and Washington, D.C. Presumably, to carry out this task you are drawing on a previously stored mental image of a map of the United States, formed perhaps in your fourth-grade geography class or maybe even from staring at a vinyl place mat showing the 50 states.

Now, referring to your image, answer the following questions: (a) Which city is farther north, Boston or Seattle? (b) Which city is farther west, New York City, or Philadelphia? (c) Which city is farther east, Reno or San Diego? Now look at Figure 9-11, which shows the actual locations of these cities. If you are like Tversky's Stanford University participants, you made errors on questions (a) and (c). Tversky (1981) argued that people's maps are systematically distorted, because people use different **heuristics,** or rules of thumb, in orienting and anchoring oddly shaped units such as continents or states. Using principles of perceptual organization, such as those discussed in Chapter 3, people try to "line up" things to make them more orderly. Thus South America is "remembered" in an image as being directly south of North America, instead of southeast of North America, as it actually is.

A similar principle applies to your location of the various cities on your map. You probably know that the state of California is west of the state of Nevada, a fact largely true. However, *parts* of Nevada are west of *parts* of California. In fact, San Diego is *east* of Reno, not west. And Seattle is significantly *north* of Boston. But your knowledge of the states' relative locations, combined with your propensity to make your mental image of the map more aligned, contributes to systematic distortions. These distortions are one way in which mental images are *not* like mental pictures.

Another way is found in the work of Chambers and Reisberg (1992). They first asked their research participants to form an image of the creature shown in Figure 9-12(A). You might recognize the creature as the ambiguous "duck/rabbit" shown in many introductory psychology textbooks. Sometimes experimenters told participants that the creature was a duck; other times, they said it was a rabbit. They presented the actual drawing for only about 5 seconds (enough time to form an image of the figure but not enough time to "reverse" the figure).

When participants had formed an image, they were then presented with a pair of duck/rabbits, either (A) and (B) or (A) and (C), and were asked to choose which had actually been presented. You'll notice that the distinctions between any pair are very subtle and hard to detect. Chambers and Reisberg (1992) found that when participants thought they were imaging a *duck,* they were well above chance at detecting the difference between (A) and (B) [the alteration in (B) is to the duck's bill] but could not clearly distinguish between (A) and (C) [the alteration in (C) is to the rabbit's nose]. Exactly the opposite pattern emerged for those who had formed an initial image of a rabbit. Chambers and Reisberg believed the reason for this effect is that people paid more attention to the region they took to be the creature's "face" and less to the back of the creature's head. In any case, the result shows that people who form images of the same physical stimulus, but who give different

**FIGURE 9-11** ■ *Map of Europe and the United States with selected cities (cylindrical projection).*

**SOURCE:** Tversky (1981, p. 413).

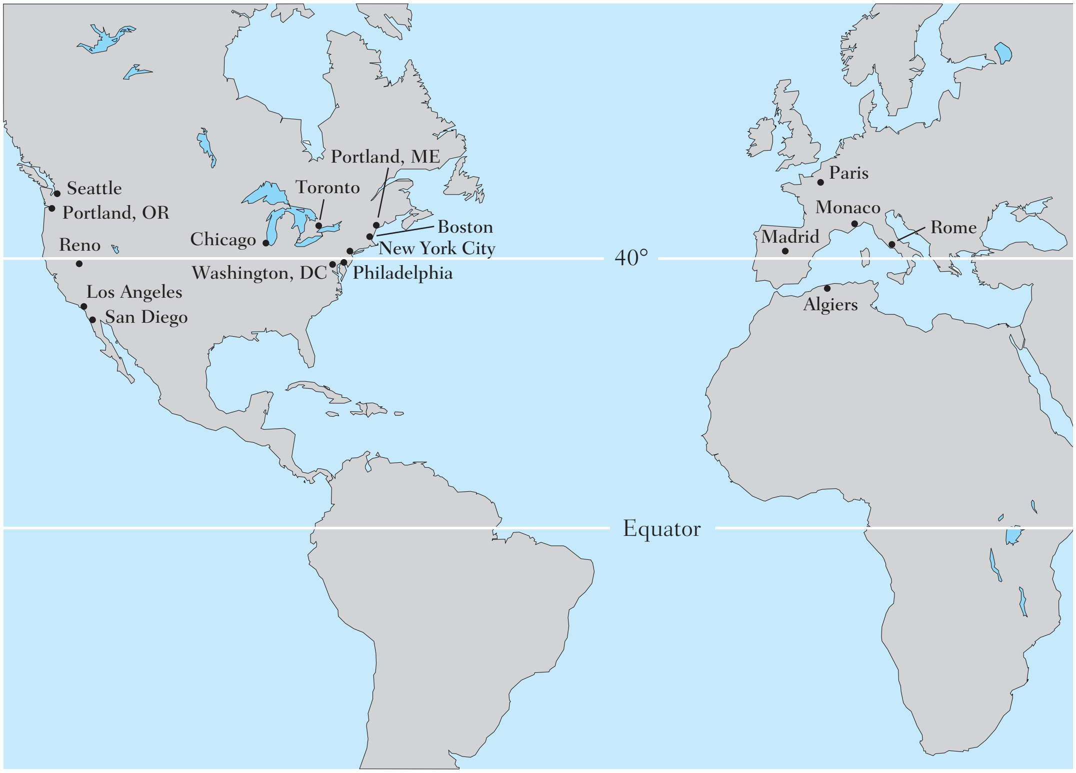
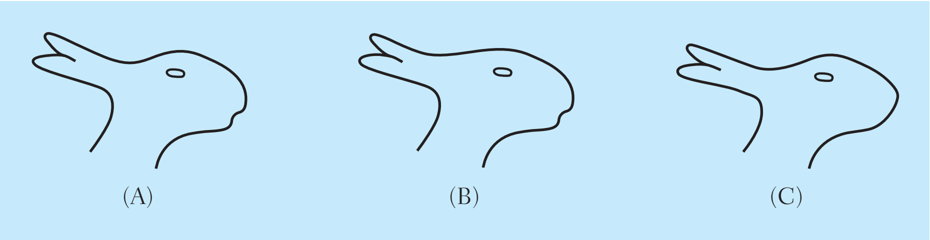

Seattle
Portland, OR
Reno
Los Angeles
San Diego
Chicago
Toronto
Portland, ME
Boston
New York City
Washington, DC
Philadelphia
40°
Equator
Paris
Monaco
Madrid
Rome
Algiers

**FIGURE 9-12** ■ *Test stimuli for Chambers and Reisberg's experiments: (A) unmodified figure, (B) modification on the duck's bill, (C) modification on the rabbit's nose.*

**SOURCE:** Chambers and Reisberg (1992, p. 152).



construals or meanings to the stimulus, actually form different images. In fact, Chambers and Reisberg reported from their previous work that even with hints and prompts, few participants spontaneously reversed their image of the duck/rabbit, although almost everyone looking at the picture of the duck/rabbit did.

This review sounds so far as if it were always beneficial to be able to construct and use mental images. But a recent study by Knauff and Johnson-Laird (2002) provides a counterexample. They studied people reasoning with what are called *three-term series problems*, such as

Tandy is furrier than Bussey.
Bussey is less furry than Eskie.
Which dog is furriest?

The authors varied the kinds of terms used in the problems. Some were easy to envisage both visually and spatially, such as *above–below* or *front–back*. In other words, it's easy to mentally image one person in front of or behind another, *and* it is easy to mentally depict the three terms. Let's say, for example, that the premises state

Tandy is in back of Bussey.
Bussey is in back of Eskie.

Then it is easy to spatially depict the relative positions of the three dogs without forming a visual image of them, as in this "map":

*(front)* Eskie Bussey Tandy *(back)*

Notice that this representation doesn't show visual details of any of the dogs. Knauff and Johnson-Laird (2002) created other problems with different content, which were easy to form mental images of, but not quite as easy to form spatial representations of—for example, *cleaner–dirtier, fatter–thinner*. If you form a representation of "Tandy is dirtier than Bussey," for instance, you probably do it by constructing a visual image of one dog more covered in mud than another one. There were also control problems, which were not easy to form any kind of image or spatial representation of (for example, *better–worse, smarter–dumber*).

Results showed that visual relations (for example, cleaner–dirtier) slowed down performance relative to either control problems (for example, better–worse) or visuospatial problems (in back of–in front of). Plausibly, the mental effort devoted to constructing the visual images used up mental capacity that could have been solely focused on drawing a logical conclusion. Thus imagery is not always a boon to cognitive performance—a lot depends on the nature of the task at hand.

## THE NATURE OF MENTAL IMAGERY

All the results reviewed so far suggest that images share some properties with pictures. People typically report their experience of images as looking at mental pictures, and the kinds of mental transformations done on images seem very similar to transformations done on pictures. This leads directly to the questions: Just what are images? What kinds of properties do images have, and how are these like and unlike the properties that real pictures have?

Presumably, answers to such questions have implications for the way information is stored, retrieved, and used. Research on visual imagery, then, can potentially tell us a great deal about how information is mentally represented and organized. Our coverage of knowledge representation (Chapter 7) and concepts (Chapter 8) focused primarily on verbal information. Research on visual imagery suggests there may be another kind of information that is stored and used.

Debate over the nature of visual images has been intense in cognitive psychology. We will review highlights of the debate here, taking a close look at the image-as-mental-picture metaphor. To organize this discussion, we will first review Ronald Finke's (1989) principles of visual imagery. Then we will examine critiques of this research and of the image–mental picture metaphor.

### Principles of Visual Imagery

Finke's (1989) principles of visual imagery, taken together, are meant to describe the fundamental nature and properties of visual images. There are five principles, and each covers a different aspect or characteristic of imagery.

#### Implicit Encoding

Finke's first principle of visual imagery states that "mental imagery is instrumental in retrieving information about the physical properties of objects, or about physical relationships among objects, that was not explicitly encoded at any previous time" (Finke, 1989, p. 7). This principle implies that images are places from which some information can be obtained, even if that information was never intentionally stored. Imagery can thus be used to answer questions for which you probably don't have a directly stored answer. The task at the beginning of this chapter—you were asked about the number of cabinet doors in the kitchen of your permanent residence—is a case in point. My guess is that if you are like most people, you've never had much reason to count kitchen cabinet doors. So this information was probably not represented directly in long-term memory. However, the information was **implicitly encoded,** meaning it was stored unintentionally along with other information that allows you to construct a visual image of your kitchen. To answer the question, then, all you need to do is form the visual image, scan it, and count cabinets.

Brooks's (1968) task, in which people had to answer questions about an outlined capital *F,* provides another illustration. Presumably, most people have never bothered to check whether each corner of an outlined capital *F* is at the top or bottom of the letter. Yet people are able to perform this task, presumably because the required information has been implicitly encoded together with the information that allows them to form a visual image of an *F.*

### Perceptual Equivalence

Finke's second principle of visual imagery has to do with the similarities between the construction of visual images and the perception of real objects and events. It states that "imagery is functionally equivalent to perception to the extent that similar mechanisms in the visual system are activated when objects or events are imagined as when the same objects or events are actually perceived" (Finke, 1989, p. 41). In other words, many of the same kinds of internal processes used in mental visualization are used in visual perception as well.

An early study by Perky (1910) bears on this principle. Perky had participants imagine that they were looking at an object (such as a tomato, a banana, an orange, a leaf) while staring at a blank screen. After they reported having formed the image, they were briefly distracted by one experimenter while another two experimenters operated an apparatus that projected faint pictures of the objects the participants were imagining. Perky found that many of the participants were unable to distinguish between their own images and the faint pictures. Presumably, this is because images share many similarities with faint pictures.

A related group of studies, including many more experimental controls, was reported by Martha Farah (1985). Participants were asked to form an image of a certain letter—for example, an *H* or a *T.* Very soon after, they were sometimes presented with one of these letters, but at a low level of contrast, making the letters very difficult to see. Those who imagined a letter first were more accurate at detecting the actual presented letter than they were at detecting another letter. These results suggest that imagery can "prime" the visual pathway used in detecting an actual stimulus (Finke, 1989). Some authors even regard visual imagery as perceptual "anticipation": the visual system "getting ready" to actually see something (Neisser, 1976).

### Spatial Equivalence

Finke's third principle of visual imagery has to do with the way that spatial information, such as location, distance, and size, is represented in visual imagery. The principle states that "the spatial arrangement of the elements of a mental image corresponds to the way objects or their parts are arranged on actual physical surfaces or in an actual physical space" (Finke, 1989, p. 61).

Much of the evidence for this principle comes from the scanning studies by Kosslyn and associates, reviewed above. The general finding is that the amount of time it takes people to scan from one element of a visual image to another corresponds to the distance between the elements in a physical representation. Thus the spatial relationships among elements of a drawing or object (for example, relative locations, distances, sizes) all seem to be preserved in the visual image of the drawing or object.

Separating the visual characteristics from the spatial characteristics of an image (or object or drawing) is quite difficult. But an ingenious series of studies by Nancy Kerr (1983) has apparently succeeded at this task. Hers was a map-scanning study, very similar to that of Kosslyn et al. (1978) described earlier. However, in this case some of the participants were congenitally blind and learned the "map" by feeling objects (each of which had a distinct shape) placed on a flat surface. Once participants had learned the locations, they heard the experimenter name a pair of objects and were asked to focus mentally on one and to imagine moving a raised dot from that object to the second. Kerr found that the greater the distance between objects, the longer it took both blind and sighted participants to scan.

Results of this study echoed those of Kosslyn et al. (1978), suggesting that visual imagery has spatial properties. The spatial properties are similar to visual representations but need not be visual, because congenitally blind people—without vision—apparently are able to make use of spatial images.

### Transformational Equivalence

Finke's fourth principle of visual imagery has to do with the way that images are mentally transformed. It states that "imagined transformations and physical transformations exhibit corresponding dynamic characteristics and are governed by the same laws of motion" (Finke, 1989, p. 93).

The best evidence for this principle comes from the studies of mental rotation. Recall that the findings from those studies suggest that mental rotation apparently works in the same way physical rotation does: It is continuous, with rotating objects moving through intermediate orientations on their way to their final orientation. The time it takes to perform mental rotation depends on how much rotation is to be done, as with physical rotation. And, as with physical rotation of an object, the whole object, and not just parts of it, is rotated. The principle of transformation equivalence extends beyond mental rotation, however, in asserting that other kinds of transformations will work with images in much the same way they work with real objects.

### Structural Equivalence

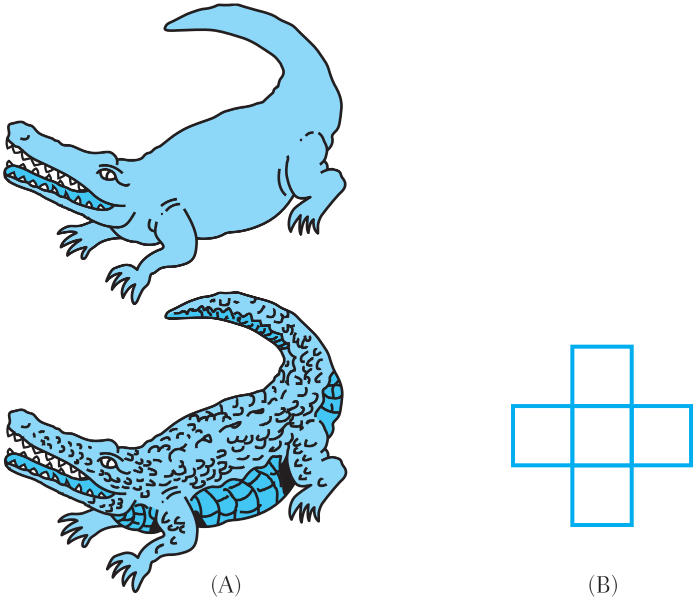
Finke's fifth principle of visual imagery has to do with the ways that images are organized and assembled. It states that "the structure of mental images corresponds to that of actual perceived objects, in the sense that the structure is coherent, well organized, and can be reorganized and reinterpreted" (Finke, 1989, p. 120).

Imagine that you need to draw a picture of an object or (if your artistic skills and inclinations are as poor as mine) that you need to look carefully at an object. How would you do this, and what properties of the object would influence the difficulty of your task? Generally speaking, the larger the object, the more time it would take to look over or to draw. Also, the more complicated the object—that is, the more different parts the object had—the harder it would be (and the longer it would take) to look at carefully or to draw. Apparently, the construction of visual images works the same way. Visual images are formed, not all at once, but in pieces that are assembled into a final rendition (Finke, 1989).

Kosslyn, Reiser, Farah, and Fliegel (1983) studied image generation as it relates to the complexity of the object to be imagined. Participants were asked to form images of pictures that differed in amount of detail, such as those in Figure 9-13(A). It took participants about one and a third times as long to form an image of the detailed pictures as it did other participants to form images of outline drawings. In a related study, the authors used geometric forms such as those shown in Figure 9-13(B) as stimuli, all of which allowed for different descriptions. For instance, Figure 9-13(B) could be described either as "five

**FIGURE 9-13** ■ *Stimuli from the Kosslyn et al. (1983) study.*

**SOURCE:** Kosslyn et al. (1983, pp. 280, 287).



(A)

(B)

squares in the shape of a cross" or as "two overlapping rectangles." Participants first read a description, then saw the corresponding figure, then covered it up and formed a visual image of the figure. Kosslyn et al. found that people given the first description took longer to form the image than did people given the second description, even though the physical pattern was the same. Notice, by the way, that it would probably be faster to draw or look over Figure 9-13(B) if you conceived of it as two rectangles than as five squares. With images, apparently, the greater the complexity of the *conceived* structure of the object, the longer it takes to assemble an image of it.

## Critiques of Mental Imagery Research and Theory

In the introduction to this chapter, I noted that the study of imagery has been controversial in psychology, and it is time now to examine the controversy. Although almost every imagery study has been subject to some debate (Finke, 1989, provides several examples), we will focus on three general and interrelated themes. The first concerns criticism of imagery research. In particular, the criticism is that the experiments themselves give enough "hints," either explicitly or implicitly, for people to perform by relying on their beliefs and knowledge rather than relying strictly on visual imagery. A second critique questions the metaphor of images as pictures. A third kind of criticism is more theoretical, questioning the need to talk about imagery as a distinct kind of internal code. We will consider each critique in turn.

### Tacit Knowledge and Demand Characteristics

Pylyshyn (1981) argued that the results from many imagery studies reflect participants' underlying and implicit **tacit knowledge** and beliefs about the task rather than their construction and manipulation of visual images. He paid special attention to image-scanning experiments. Participants' scanning time is proportional to distance scanned, Pylyshyn asserted, because they know that the amount of time it takes to physically scan between two points in a visual display depends on distance *and* because they expect the experiment to demand this kind of performance.

Finke (1989) explained how this knowledge and expectation could distort results. Imagine you want to move an object (say, your coffee cup) from one location (the right side of your desk) to another (the left side of your desk). You could (à la movie scenes in western bars) try to slide the cup across the desk, but it would probably be safer to pick up your cup and place it in the new location. Imagine, for the sake of argument, that you could move the cup instantaneously, regardless of the distance (maybe "teleporting" it from one set of coordinates to the other, à la *Star Trek*). Suppose, however, you believed or expected that the amount of time it took to move the coffee cup to the new location should depend on the total distance from the old to the new location. You could adjust your time by pausing and holding the cup over the new location for some amount of time before you placed it down on the desk. Then your reaction time in moving the cup would be proportional to the distance the cup moved, although the time would depend arbitrarily on the time you chose to pause.

Pylyshyn's (1981) argument was that people may be "mentally pausing" in image-scanning experiments because of their beliefs and expectations about what the experimenters want them to do. Tasks that are affected by people's beliefs and expectations are termed by Pylyshyn to be *cognitively penetrable*. Some tasks make it obvious to participants how they ought to perform. The instructions, the tasks themselves, or something else about the situation cues the person on how to behave. Such a task is said to have **demand characteristics** (Orne, 1962). In other words, the task "demands" somehow that the person behave in a certain way. Typically, participants in psychology experiments try to please and may behave artificially just to perform in ways they believe will satisfy the experimenter.

Moreover, sometimes experimenters unconsciously give subtle cues to participants. Intons-Peterson (1983) has argued that these **experimenter expectancy effects** have influenced at least some of the imagery investigations. In various studies, she had undergraduate experimenters conduct a number of imagery studies. Some of the experimenters were led to believe that the results would turn out one way; the other experimenters were led to believe the opposite. In all the studies, participants performed as the experimenters expected them to.

In one study, Intons-Peterson (1983) used four undergraduate experimenters, all known "for their intelligence, dependability, good judgment, and maturity" (p. 396). None was familiar with the imagery literature. Each experimenter was assigned to supervise a total of 18 participants in three different conditions in a mental rotation study. Some participants were "primed" by either seeing or imagining a stimulus before each trial; participants in a control condition received no primes. Two of the four experimenters were told to expect that imaginal primes (primes that participants were asked to imagine) would be more effective than perceptual primes (primes actually presented to participants). The other two experimenters were told the opposite: Perceptual primes would be more effective than imaginal primes. Although all stimuli were presented by microcomputer, and although experimenters were not in the same room with the participants, except initially when they read instructions, the results mirrored the experimenters' beliefs. Participants supervised by experimenters who believed imaginal primes would be more effective than perceptual primes produced data to support that belief; participants supervised by the other experimenters produced data that resulted in the opposite findings.

Intons-Peterson (1983) found similar results in imaginal scanning experiments. She concluded that participants in imagery experiments were sensitive to subtle, unintentional cues given by experimenters, including slight differences in intonation or pauses when reading instructions. Intons-Peterson further argued that imagery research, by virtue of the subjective nature of the phenomenon, may be especially vulnerable to demand characteristics and experimenter expectations. Although she did *not* assert that results from all visual imagery experiments are the result of experimenter effects and demand characteristics, she did warn that visual imagery researchers must take special care to minimize these effects.

### The Picture Metaphor

Much of the discussion so far has suggested an analogy between pictures and images. Some psychologists speak casually of visual images as "mental pictures." The question is, How far does the analogy go? As Pylyshyn (1973) pointed out, pictures and images differ in several ways. Perhaps the most important difference is that you can physically look at a picture without first knowing what it's a picture of (say, if someone wordlessly hands you a photograph, and you ask, "What's this?"), but you cannot "look" at an image unless you first know what it is. After all, images are internal constructions formed with some intention in mind. You don't just spontaneously create random images; rather, you form images of particular things.

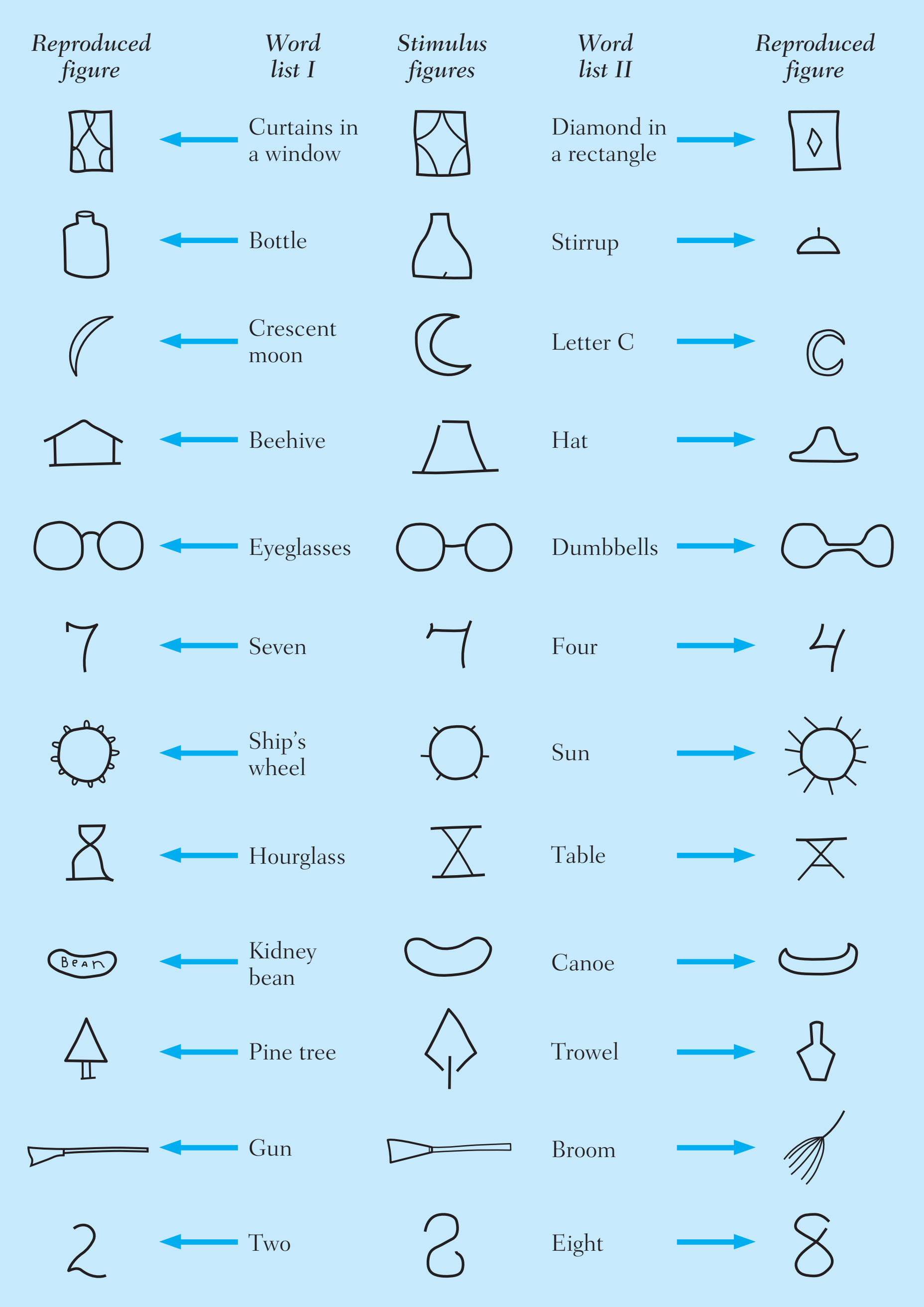
Second, pictures and images are disrupted, and disruptable, in different ways. You can cut a photograph in half, with the result that arbitrary parts of the objects depicted disappear. Images are organized more meaningfully, and when they fade, only the meaningful parts disappear (Finke, 1989).

Last, images seem more easily distorted by the viewer's interpretations than are pictures or photographs. Remember Bartlett's (1932) work on story recall? (See Chapter 6 if you need to review.) We saw how people's memory for stories changed over time and often depended on their initial or subsequent interpretations. So also with images. Carmichael, Hogan, and Walter (1932) presented participants with patterns such as those in Figure 9-14, with one of two labels (different participants were given different labels). Participants' later reproductions of the patterns (presumably based on imagery) were distorted in accordance with the label initially provided, as shown in the figure.

Similarly, Nickerson and Adams (1979) have shown that people make many errors when trying to reproduce their images of familiar objects. Try drawing a picture of a U.S. penny without looking at one, and then compare it to a real penny. Is Lincoln facing the right way? Is the right motto in the right place? How about the date? Notice in this case that your image probably has far less information in it than would a clear picture or photograph of a penny.

**FIGURE 9-14** ■ *Materials from the Carmichael et al. (1932) study.*

**SOURCE:** Carmichael et al. (1932, p. 80).


Reproduced figure
Word list I
Stimulus figures
Word list II
Reproduced figure
Curtains in a window
Diamond in a rectangle
Bottle
Stirrup
Crescent moon
Letter C
Beehive
Hat
Eyeglasses
Dumbbells
Seven
Four
Ship's wheel
Sun
Hourglass
Table
Bean
Kidney bean
Canoe
Pine tree
Trowel
Gun
Broom
Two
Eight

What's the significance of finding differences between images and pictures? Visual images are thought to be one means of internal coding and representation of information. Although many cognitive psychologists believe that visual imagery exists as a distinct mental code, and although they believe the code has many visual and/or spatial qualities, the evidence to date suggests that the visual image-as-picture analogy works only roughly.

## Propositional Theory

A broader criticism of work on imagery is theoretical and is aimed at the very premise behind the field. Proponents of *propositional theory* reject the idea that images serve as a distinct mental code for representing information. Instead, propositional theorists believe there is a single code, neither visual nor verbal but propositional in nature (Anderson & Bower, 1973), that is used to store and mentally represent all information. As we saw in Chapter 7, propositions are a means of specifying relationships between different concepts.

For example, the idea that New York is a city located to the west of Boston might be represented by the following propositions: CITY (New York); WESTOF (New York, Boston). Propositions can be linked together in networks, with two closely related ideas joined by sharing a number of propositions.

Pylyshyn (1973) asserted that propositional theory could explain the results of imagery experiments. His idea was that all information is mentally represented and stored by propositions. Participants in visual imagery experiments might *look* as if they were consulting or manipulating internal visual representations, but they would actually be using internal propositional representations, the same kind of representations that underlie their processing of verbal material, such as sentences or stories.

Two studies by Kosslyn (1976) attempted to test this assertion. Kosslyn first tested the *association strength* between animals and their physical attributes. For instance, for most people "claws" are more strongly associated with "cat" than is "head," although cats, of course, have both. Kosslyn found that when people did *not* use imagery, they were faster to verify that cats had claws (high association value, small visual part of a cat) than that cats had heads (low association value, large visual part of a cat). Propositional theory would predict that the higher the association value, the more propositions relating the two items, and thus the faster the verification time (Finke, 1989). However, when participants reported having used imagery to do the task, their reaction times went in the opposite direction. Here, they were faster to verify visually larger parts with low association values than visually smaller parts with higher association values. Apparently, using imagery results in performance that propositional theory does not predict.

What does it matter in the real world whether people use imagery as a means of coding information? Understanding how and under what circumstances people mentally represent information is crucial to explaining how they carry out a variety of cognitive tasks. If they use different codes for different tasks, and we can make good predictions about when they use which code, we can perhaps predict when they are likely to be able to do things easily, and when they are not.

## ■ NEUROPSYCHOLOGICAL FINDINGS

Farah (1988) reported on the work of a number of investigators examining neuropsychological aspects of visual imagery. Some work has examined the pattern of blood flow in the brain. Cerebral blood flow is thought to provide a fairly precise measure of brain activity in a particular region. Roland and Friberg (1985) asked people to perform three cognitive tasks while their cerebral blood flows were being monitored. The tasks were mental arithmetic, memory scanning of an auditory stimulus, and visual imagery (visualizing a walk through a familiar neighborhood). The experimenters made sure the tasks were approximately equal in difficulty. They found that each person tested showed massive activation in the parts of the brain important for visual processing of information (mostly in the occipital lobe and other posterior regions) during the imagery task. During the other two tasks, however, there were no such increases in cerebral blood flow to those parts. Farah and her colleagues have replicated these results using other neuropsychological measures, such as event-related potentials (ERPs) measuring electrical activity in the brain (Farah, Péronnet, Gonon, & Giard, 1988).

Other investigators report a wealth of studies showing that the creation of visual images activates those areas of the brain involved in visual processing (Kosslyn & Ochsner, 1994; Miyashita, 1995). These regions are often located in the occipital lobe, that region of the cerebral cortex devoted to visual processing. In one study, for example, Kosslyn, Thompson, Kim, and Alpert (1995) tested 12 volunteers asked to form images of previously memorized line drawings of common objects. They were also asked (in different parts of the testing session) to form their images at different sizes. During the tasks, the cerebral blood flow of the volunteers was monitored using PET scans. Results indicated that all the imagery tasks produced activation in the visual cortex, replicating many previous findings, such as those just described. Of greater interest was the fact that the specific area of the occipital lobe showing maximal activation differed depending on whether the image created was small, medium, or large.

Zatorre, Halpern, Perry, Meyer, and Evans (1996) conducted a study similar in spirit, during which the cerebral blood flow of 12 participants was measured while the participants either (a) saw two words and judged which was longer, (b) saw two words from a song while hearing the song and judged whether a pitch change occurred in the song between the two words, or (c) again saw the two words from the song *without* hearing the song but were still asked to judge whether a pitch change occurred in the song. Tasks (b) and (c) led to similar patterns of cerebral blood flow changes with respect to the control condition, (a). During both Task (b) and Task (c), there was noticeable activity in both hemispheres in the secondary auditory cortex, in the temporal lobes. Imagining the songs led to somewhat weaker activation than did actually hearing the songs.

O'Craven and Kanwisher (2000) showed additionally in an fMRI study that when people form a mental image of faces, a different area of the brain becomes activated than when they imagine a place. When participants formed images of faces, the *fusiform face area* of the brain was activated—the same area that becomes activated when subjects view photographs of faces. (The fusiform face area is located in the occipital-temporal areas.) Conversely, when participants formed a mental image of a place, the *parohippocampal place area* of the brain (located in the ventromedial area) was active—just as it is when people view photographs of complex scenes.

How can neuropsychological findings bear on the controversies in the literature on visual imagery? Neuropsychological work by Farah (1985) is particularly effective in addressing the issues of demand characteristics. Farah argued that the data from her laboratory, showing that visual imagery involves activation of the same parts of the brain used in vision, are not susceptible to a demand characteristics explanation unless certain questionable assumptions are made:

> A tacit knowledge account of the electrophysiological and blood flow data, implicating the use of cortical visual areas during visual imagery activity, would need to include the following two assumptions: (a) that subjects know what parts of their brains are normally active during vision and (b) that subjects can voluntarily alter their brain electrical activity, or modulate or increase regional blood flow to specific areas of their brains. (Farah, 1985, p. 314)

Kosslyn et al. (1995) argued that their data also argue against the propositional account of visual images. The fact that visual processing areas become active when visual images are formed makes a strong case for the proposal that images are processed visually and/or spatially and that the findings from purely cognitive tasks are not simply produced by people's tacit theories of how imaginal processing ought to function.

## SPATIAL COGNITION

The study of visual imagery can be construed as part of a broader picture: **spatial cognition,** or how people represent and navigate in and through space (Montello, 2005). That is, how do we acquire, store, and use mental representations of spatial entities, and use them to get from point A to point B? One example of a spatial entity might be a "cognitive map"—a mental depiction of some part of our environment, presumably showing major landmarks and spatial relationships among them.

For example, right where you are sitting (or standing, or lying down), point in the direction of the building in which your cognitive psychology class is held. To do this, presumably you call upon some stored knowledge of the relationship between your current location and the specified location. Opinions vary as to how maplike a cognitive map really is. (You might note a similarity here to the debate over how picturelike a visual image is.) In any case, most agree that cognitive maps are mental constructs people use to navigate spatially through an environment, especially one that is too large to be immediately perceived (Kitchin, 1994).

Barbara Tversky (2005) notes that in the realm of spatial cognition, there are really a number of different kinds of spaces to be distinguished. The way people think about space depends on which kind of space is under consideration. Each kind of space seems to have different attributes and organization.

The first kind of space is the **space of the body.** This space includes knowledge of where the different parts of one's body are located at any given moment (such as knowing that my right foot currently rests flat against the floor but my left foot is wrapped around the bottom of my desk chair); knowing what other objects different body parts are interacting with (my fingers with the keyboard; my derriere with the seat of the chair); as well as internal sensations (my stuffy sinuses, the slight chill I'm feeling from my underheated office). I use my knowledge of the space of the body to direct different parts of my body spatially—as I reach for something, duck to avoid something, walk or run toward something.

The second kind of space is the **space around the body.** This space refers to the area immediately around you: the room you are in, say, or the region in which you can easily perceive and act on objects. Tversky's work suggests that people localize objects in this space along three axes that are extensions of the body. One axis is the front–back axis; another is the up–down axis, and the third is the left–right axis. Studies by Tversky and colleagues had people imagine being in a particular space and then locating an imaginary object in that space; people heard narratives describing them standing, say, in a hotel lobby or a museum, with objects on all six sides of their body (front, back, at the head, at the feet, to the right, to the left). Next they were asked to imagine themselves

Michael Clark/Getty Images

*These hikers are immersed in what Tversky calls the "space of navigation," as they explore this canyon.*

facing a different direction, and then to locate objects while facing this new direction. Times to "retrieve" objects at the head and feet were consistently fastest; times along the left–right axis were consistently slowest (Tversky, 2005).

The **space of navigation** refers to larger spaces—ones we walk through, explore, and travel to and through. In Tversky's words:

> Constituents of the space of navigation include places, which may be buildings or parks or piazzas or rivers or mountains, as well as countries or planets or stars, on yet larger scales. Places are interrelated in terms of paths or directions in a reference frame. The space of navigation is too large to perceive from one place so it must be integrated from different pieces of information that are not immediately comparable. Like the space around the body, it can be acquired

> from descriptions and from diagrams, notably maps, as well as from direct experience. One remarkable feature of the human mind is the ability to conceive of spaces that are too large to be perceived from one place as integral wholes. In order to conceive of spaces of navigation as wholes, we need to paste, link, join, superimpose, or otherwise integrate separate pieces of information. (p. 9)

When we give directions to someone, we are dealing with the space of navigation. Whether we adopt a "route" perspective and give those directions in terms of landmarks ("go straight two blocks till you come to the gas station, then take a right and go until you see the red barn, then turn left") or a "survey" perspective and give directions in terms of a bird's-eye view ("Watson dorm is two blocks east of the chapel and one block southeast of Goodsell Observatory"), we communicate some spatial information. However, the representations we form within the space of navigation aren't always accurate or complete. Thus, Tversky (2005) prefers the term "cognitive collage" to the term "cognitive map." Cognitive collages are subject to systematic errors and distortions, as we saw earlier with people's inappropriate beliefs about whether Seattle or Boston is farther north.

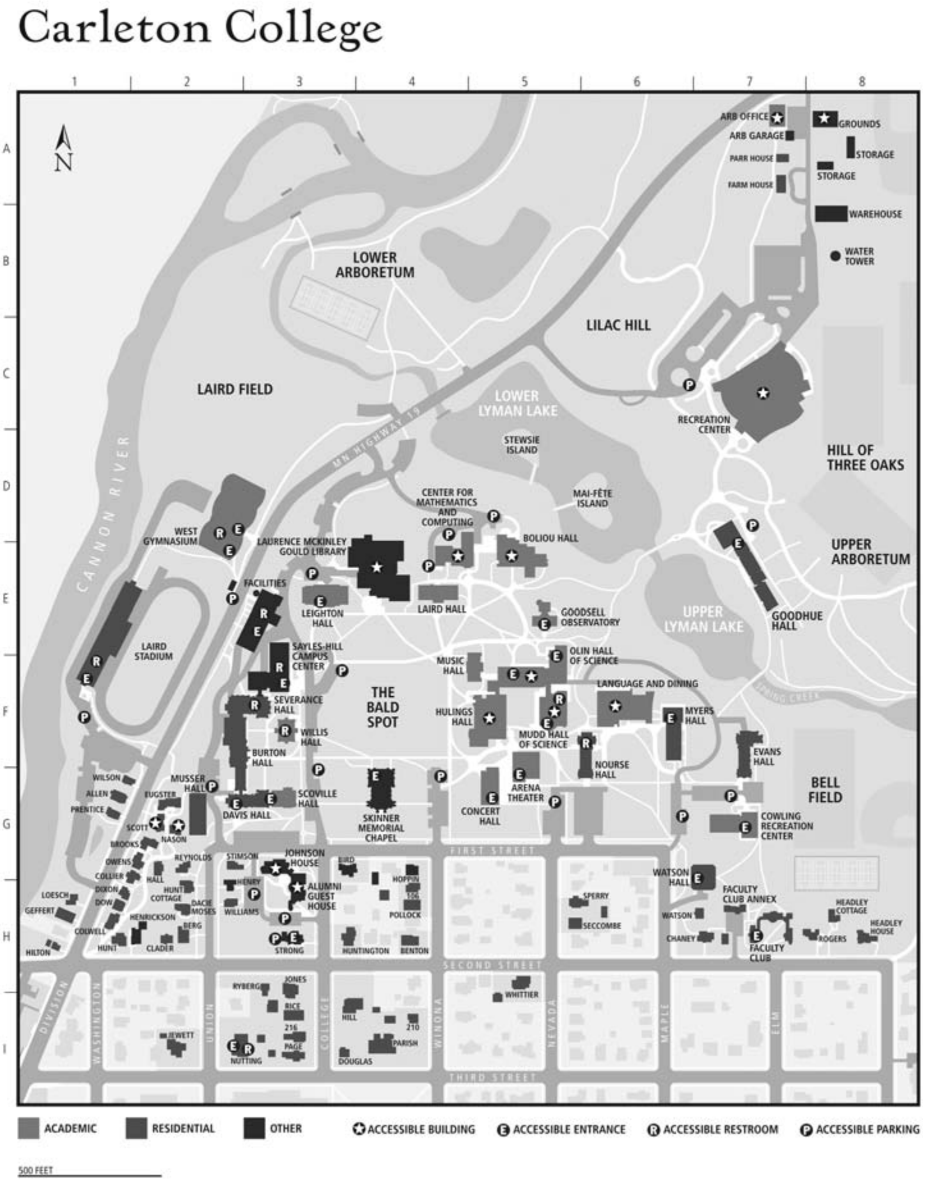
These ideas were instantiated in a senior honors thesis conducted by one of my students, Drew Dara-Abrams (2005). Drew created a task in which participants (students at Carleton College) were shown cutout versions of different campus buildings and asked to place each on a map as accurately as possible. Figure 9-15 shows an actual map of the campus with the cutouts correctly placed; Figure 9-16 shows the cutout task as it was presented to research participants.

Results showed that participants were likely to make "neater" maps in the cutout task (Dara-Abrams, 2005). That is, they systematically arranged the cutouts along orthogonal lines, making buildings line up more neatly on lines running north–south and east–west than the buildings actually do. They were also likely to rotate buildings so that they all lined up along vertical or horizontal orientations—that is, to avoid placing the buildings diagonally, even though several of our campus buildings do have a "diagonal" orientation. Such work replicated earlier findings by Tversky (1992) on people's memory for maps. For example, people frequently think of South America as directly south of North America, even though it is really more southeast. The twist in Drew's thesis was that the space of navigation used by his participants was learned through their actual navigation on the campus, not from a map-learning session.

Montello (2005) has argued that navigation consists of two major components: locomotion (moving the body over terrain) and wayfinding (planning and making decisions about where to go and how to get there). The investigation of

**FIGURE 9-15** ■ *Actual map of the Carleton College campus.*

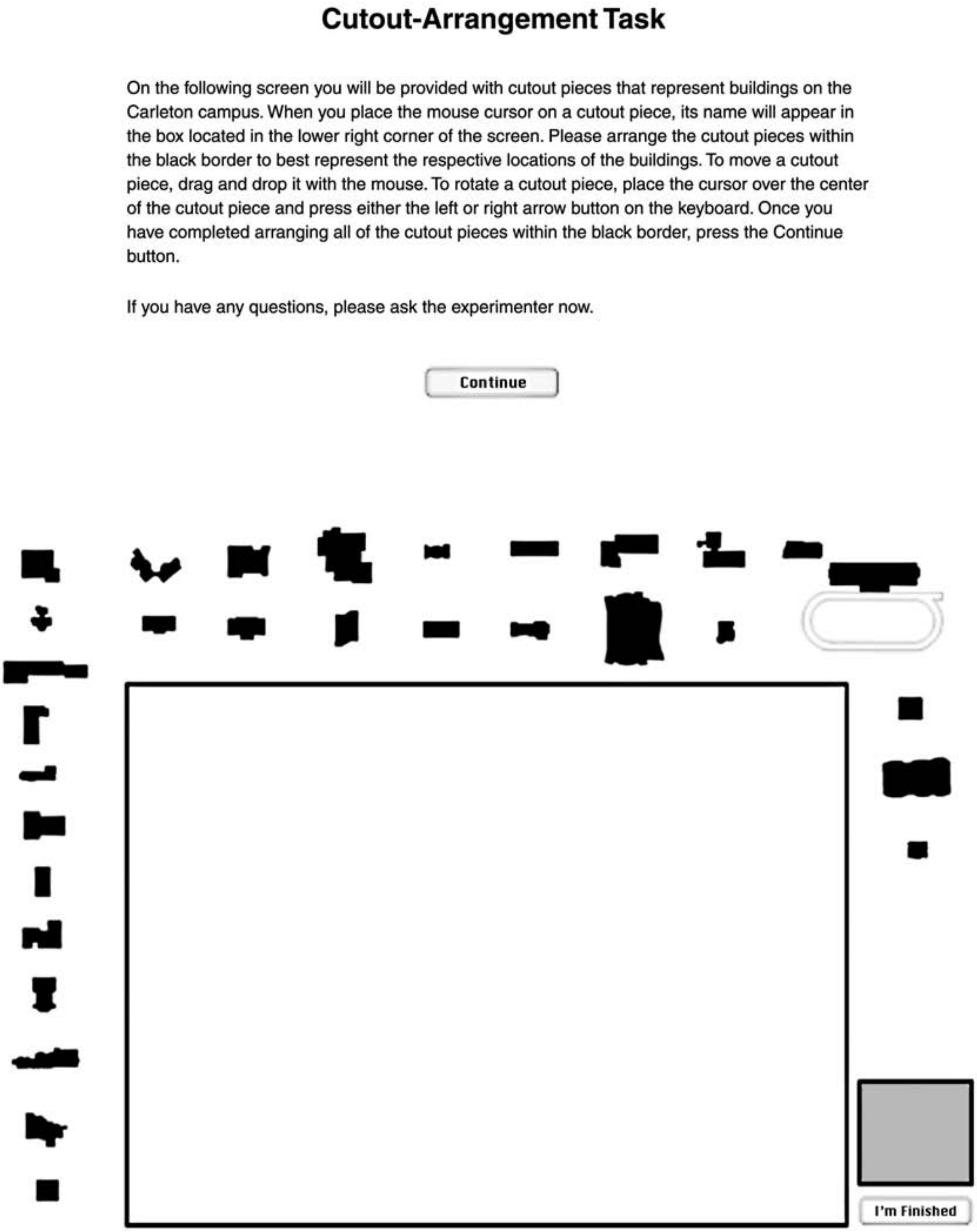
**SOURCE:** Dara-Abrams (2005).


Carleton College
1
2
3
4
5
6
7
8
A
B
C
D
E
F
G
H
I
N
ARB OFFICE
ARB GARAGE
PARR HOUSE
FARM HOUSE
GROUNDS
STORAGE
STORAGE
WAREHOUSE
WATER TOWER
LOWER ARBORETUM
LILAC HILL
LAIRD FIELD
LOWER LYMAN LAKE
STEWSIE ISLAND
RECREATION CENTER
HILL OF THREE OAKS
MN HIGHWAY 19
CANNON RIVER
CENTER FOR MATHEMATICS AND COMPUTING
MAI-FÊTE ISLAND
BOLIOU HALL
UPPER ARBORETUM
WEST GYMNASIUM
LAURENCE MCKINLEY GOULD LIBRARY
FACILITIES
LEIGHTON HALL
LAIRD HALL
GOODSELL OBSERVATORY
UPPER LYMAN LAKE
GOODHUE HALL
LAIRD STADIUM
SAYLES-HILL CAMPUS CENTER
MUSIC HALL
OLIN HALL OF SCIENCE
LANGUAGE AND DINING
SPRING CREEK
THE BALD SPOT
SEVERANCE HALL
WILLIS HALL
HULINGS HALL
MUDD HALL OF SCIENCE
MYERS HALL
EVANS HALL
BURTON HALL
NOURSE HALL
BELL FIELD
WILSON
ALLEN
PRENTICE
MUSSER HALL
EUGSTER
DAVIS HALL
SCOVILLE HALL
SKINNER MEMORIAL CHAPEL
CONCERT HALL
ARENA THEATER
COWLING RECREATION CENTER
SCOTT
NASON
BROOKS
OWENS
COLLIER
DIXON
DOW
LOESCH
GEFFERT
COLWELL
HILTON
HUNT
HALL
HUNT COTTAGE
REYNOLDS
DACIE MOSES
HENRICKSON
BERG
CLADER
STIMSON
HENRY
WILLIAMS
JOHNSON HOUSE
ALUMNI GUEST HOUSE
STRONG
BIRD
HOPPIN
106
POLLOCK
HUNTINGTON
BENTON
FIRST STREET
SPERRY
SECCOMBE
WATSON HALL
WATSON
CHANEY
FACULTY CLUB ANNEX
FACULTY CLUB
HEADLEY COTTAGE
HEADLEY HOUSE
ROGERS
SECOND STREET
DIVISION
WASHINGTON
UNION
COLLEGE
WINONA
NEVADA
MAPLE
ELM
JEWETT
RYBERG
JONES
RICE
216
PAGE
NUTTING
HILL
210
PARISH
DOUGLAS
WHITTIER
THIRD STREET
ACADEMIC
RESIDENTIAL
OTHER
ACCESSIBLE BUILDING
ACCESSIBLE ENTRANCE
ACCESSIBLE RESTROOM
ACCESSIBLE PARKING
500 FEET

how people (and animals) navigate shows integration of a number of cognitive processes we have previously encountered, including perception, attention, memory, and knowledge representation, as well as some topics (planning, reasoning, decision making) yet to come.

**FIGURE 9-16** ■ *Cutout task presented to participants in Dara-Abrams (2005) study.*

**SOURCE:** Dara-Abrams (2005).



**Cutout-Arrangement Task**

On the following screen you will be provided with cutout pieces that represent buildings on the Carleton campus. When you place the mouse cursor on a cutout piece, its name will appear in the box located in the lower right corner of the screen. Please arrange the cutout pieces within the black border to best represent the respective locations of the buildings. To move a cutout piece, drag and drop it with the mouse. To rotate a cutout piece, place the cursor over the center of the cutout piece and press either the left or right arrow button on the keyboard. Once you have completed arranging all of the cutout pieces within the black border, press the Continue button.

If you have any questions, please ask the experimenter now.

## SUMMARY

1. Visual images are mental representations of perceptual experiences. There are also auditory, olfactory, cutaneous, and other images, each thought to be a mental representation of a perceptual experience.
2. Visual images are often used in mnemonics, techniques that improve the chances of recalling information. Some examples include the method of loci and the method of interacting images.
3. The dual-coding hypothesis of memory states that when information can be coded both by a verbal label and by a visual image, the memorability of that information is enhanced relative to information that can be coded only by a verbal label.
4. Not all psychologists believe in the existence of these two distinct codes. However, despite the theoretical possibility that only one propositional code is used to perform the visual imagery tasks described, many cognitive psychologists are persuaded by the evidence of the existence of some sort of a distinct visual-spatial code.
5. Research on visual imagery has suggested that images function in some ways like internal pictures, undergoing certain kinds of mental operations and transformations. These mental operations and transformations appear to function in ways similar to corresponding physical operations and transformations.
6. However, other researchers and theoreticians have pointed out limitations in the image-as-picture metaphor. There are a number of ways in which images work differently from pictures. Some investigators, such as Farah (1988), have therefore concluded that "imagery is not *visual* in the sense of necessarily representing information acquired through visual sensory channels. Rather, it is visual in the sense of using some of the same neural representational machinery as vision" (p. 315).
7. Finke (1989) has proposed five principles of visual imagery: (a) implicit encoding, (b) perceptual equivalence, (c) spatial equivalence, (d) transformational equivalence, and (e) structural equivalence.
8. Neuropsychological findings, taken in conjunction with the older studies, can help distinguish among different proposals. The studies that show activation of the visual cortex when forming imagery provide convincing evidence that the processing of visual images and the processing of visual perceptual information share a neural substrate.
9. Images are necessarily a private mental experience. It is all the more exciting, then, when results from cognitive psychology and neuropsychology converge. Many consider the empirical investigations of imagery a major victory in the larger task of understanding how cognition, a collection of private mental experiences, functions.

10. Visual imagery can be seen as part of a broader topic of spatial cognition. Spatial cognition encompasses the ways in which people acquire, store, and use information about spatial properties to navigate.

## REVIEW QUESTIONS

1. Describe four mnemonics, two that rely on visual imagery and two that don't, and contrast the underlying mechanisms thought to account for their effectiveness.
2. Describe and contrast the dual-coding hypothesis and the relational-organizational hypothesis, and describe experimental means of distinguishing between them.
3. What interpretations have cognitive psychologists performing mental rotation studies (for example, Shepard, Metzler, and Cooper) drawn from their findings? In what ways are such interpretations consistent with those drawn by Kosslyn from his image-scanning experiments?
4. Describe and discuss Finke's five principles of imagery.
5. Pylyshyn asserted that many of the results from visual imagery experiments are attributable to tacit knowledge and demand characteristics. Describe and critique his arguments.
6. What objections did Intons-Peterson raise to some of the findings from visual imagery experiments? In your view, how strong are such objections? Defend your view.
7. In what ways are visual images like pictures? In what ways are they different?
8. Some researchers have used neuropsychological findings to try to resolve some of the controversies in the imagery field. How decisive are such findings? Explain.
9. Describe Tversky's proposal for different "spaces" of which people have knowledge. Why is it important to distinguish among them?

## KEY TERMS

demand characteristic
dual-coding hypothesis
experimenter expectancy effect
heuristic
imaginal scanning
implicit encoding
mental rotation
method of loci
mnemonics
relational-organizational hypothesis
space around the body
space of navigation
space of the body
spatial cognition
tacit knowledge
visual image

## CogLab DEMONSTRATIONS

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

As its name suggests, the **Mental Rotation** demonstration gives a re-creation (with some slight variation of stimuli) of the famous Shepard and Metzler mental rotation task.

## WEB RESOURCES

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

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PART

# IV

# Use and Manipulation of Information

10 Language
11 Thinking and Problem Solving
12 Reasoning
13 Making Decisions

# CHAPTER 10

# Language

**The Structure of Language**
- Phonology
- Syntax
- Semantics
- Pragmatics

**Language Comprehension and Production**
- Speech Perception
- Speech Errors in Production
- Sentence Comprehension
- Comprehending Text Passages
- Story Grammars
- Gricean Maxims of Conversation

**Language and Cognition**
- The Modularity Hypothesis
- The Whorfian Hypothesis
- Neuropsychological Views and Evidence

Right now, as you read this sentence, you are engaged in the process of language comprehension. As I write this sentence, I am engaged in language production. Probably neither of us finds our behavior remarkable. We comprehend and produce language all day long—when we read or speak, when we listen to dialogue or conversations, when we struggle to write a term paper (or a textbook chapter), or even when we compose the most mundane pieces of prose ("Gone to the library—meet me at 5 at the car"). In short, we take our language abilities for granted.

Evidence is abundant, however, that language use and abilities are not so straightforward. Researchers studying artificial intelligence have found it extremely difficult to build computer systems that can understand language (spoken or written) as easily as a 4-year-old child can. Parents of toddlers can attest that although language acquisition is rapid, a person takes several years to become proficient. Many high school and college students come to appreciate fully the complexities of language only when they try to master a second one.

Language use is intimately connected to cognition. Much of the information we receive comes from spoken or written language; we use language to ask questions, explain conclusions, clarify problems, and so on. Like perception or memory, then, language seems to be a crucial cognitive ability so easily used that we typically overlook its complexity.

In this chapter, we will first look at the structural elements of a language: the pieces or aspects that go into the elaborated, rule-governed, and creative communication systems we recognize as different human languages. We will then examine models of language comprehension and production: how we understand and create spoken discourse and written material. Finally, we will consider the relationship between language and other cognitive processes.

Continuing themes from earlier chapters, we will see that some language processes are bottom-up, or driven by incoming data, whereas others are top-down, or driven by the listener or speaker's expectations. Some language processing appears automatic, carried out without awareness or intention. Other language processing, of course, is performed intentionally and with effort. Thus processing language is very clearly constrained by other cognitive processes we have studied—perception, attention, and memory, in particular. At the same time, language is used in cognitive processes described in later chapters—thinking, planning, reasoning, and making decisions.

It is important to define language precisely and, in particular, to distinguish between *language* and *communication.* Although language is often used as a communication system, there are other communication systems that do not form true languages. Many bees, for example, use elaborate dances to tell other bees about a newfound source of food. Although this dance communicates where the food is, it can *only* communicate that kind of message—the dance can't inform the bees about an interesting sight to see along the way to the food source. Birds have songs and calls to broadcast territorial boundaries or to attract mates (Demers, 1988). But again, these communication systems can send only very specific messages. How do these systems of communication differ from language? To decide, we must first define a language.

A natural language has two necessary characteristics: It is *regular* (governed by a system of rules, called a **grammar**), and it is *productive,* meaning that infinite combinations of things can be expressed in it. Other characteristics of human languages include *arbitrariness* (the lack of a necessary resemblance between a word or sentence and what it refers to) and *discreteness* (the system can be subdivided into recognizable parts—for example, sentences into words, words into sounds; see Demers, 1988, or Hockett, 1960).

Using these criteria, we can conclude that bees do not have a language, because the physical motions in the dance carry information about the nectar source (lack of arbitrariness). For instance, the direction of the food source is indicated quite literally by the direction of the bee's dance, and the distance is indicated in the dance by the rate at which the bee wiggles (Harley, 1995). Further, the dances are restricted to communicating about food sources, thus failing on the grounds of productivity. Bird songs and calls also cannot be classified as languages, primarily on the grounds of productivity, because the songs and calls communicate only about certain topics (mostly mates, predators, and territories; see Demers, 1988). These illustrations help clarify the relationship between language and communication systems: All human languages are communication systems, but not all communication systems have the prerequisites to be classified as natural languages.

Investigators have studied animal communication during various endeavors, such as play or tool use (Bekoff & Allen, 2002; Hauser, 2000), and many others have attempted specifically to teach various language and communication systems to chimpanzees (Gardner & Gardner, 1971; Premack, 1976; Savage-Rumbaugh, McDonald, Sevcik, Hopkins, & Rubert, 1986; Terrace, 1979). Some investigators have taught their participants to use sign language; others have relied on systems of plastic tokens or geometric symbols. Most agree chimpanzees can be taught to use symbols or signs to make requests or label objects (for example, "Kanzi chase Sue," "Me more eat," or "Orange juice"). A study by Sue Savage-Rumbaugh et al. (1986) suggests that pygmy chimpanzees can even learn to spontaneously use symbols to communicate,

Renee Lynn/Getty Images

*Although these animals are clearly communicating, there is little evidence that their communication system forms a true language.*

learn to use symbols simply by watching others (people or chimpanzees) use them, and learn to understand spoken English words.

Despite these impressive findings, most researchers in this field would agree there are substantial differences between the language that even the brightest and most linguistically sophisticated chimpanzees have acquired to date and the language of most 3-year-old children. Most would agree, too, that although chimpanzees can acquire many vocabulary items and some rudimentary language structure, their communication system still falls far short of any known human language. To understand why, we need to review the structure of human language in detail.

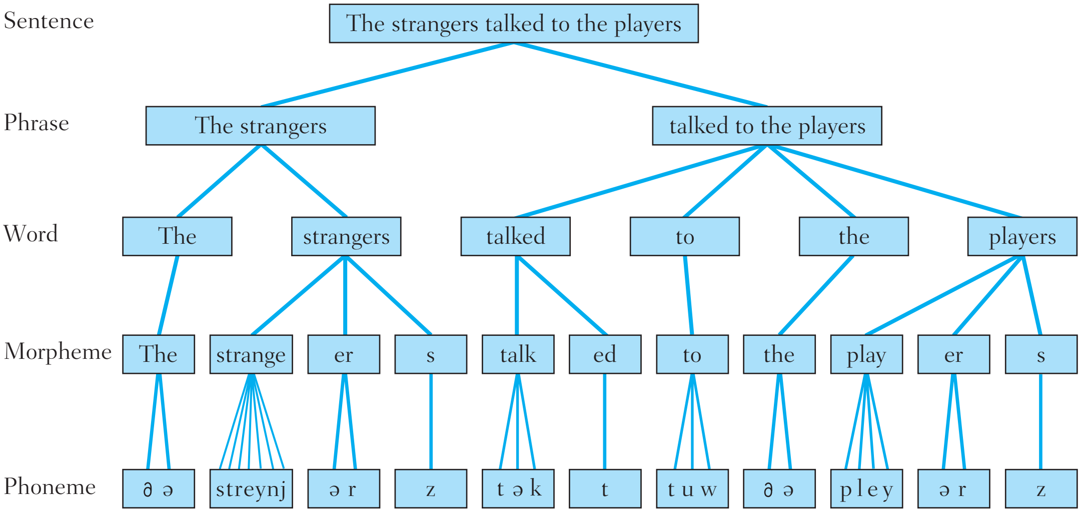
## THE STRUCTURE OF LANGUAGE

As with any complex ability, language comprises a number of systems working together. I will illustrate some of the ways in which the systems work together through the example of conversation. I use the example of a conversation, because it is considered a basic setting for language, one common to all people, even the estimated one sixth of the world's population who lack literacy necessary for reading and writing (Clark & Van Der Wege, 2002).

When you have a conversation, you first have to listen to and perceive the sounds the speaker directs at you. Different languages have different sounds (called **phonemes**). The study of the ways in which phonemes can be combined in any given language constitutes the study of *phonology.* Next you have to put the sounds together in some coherent way, identifying the meaningful units of language, an aspect known as *morphology.* Word endings, prefixes, tense markers, and the like are critical parts of each sentence. Some of the **morphemes** (smallest meaningful units of language) are words, and you also need to identify these and to determine the role each word plays in a sentence.

To do so, you need to determine the **syntax,** or structure, of each sentence. Figure 10-1 illustrates the different "levels" of language a simple sentence can be broken into. We will come back to the topic of sentence structure very shortly. A syntactically correct sentence does not by itself make for a good conversation. The sentence must also mean something to the listener. **Semantics** is the branch of linguistics and psycholinguistics devoted to the study of meaning. Finally, for the conversation to work there must be some flow or give-and-take. Listeners must pay attention and make certain assumptions, and speakers must craft their contributions in ways that will make the listener's job feasible. This aspect of language, **pragmatics,** will conclude our discussion of the structure of language. Keep in mind throughout that although the various aspects of language will be discussed separately, in actual conversation they must work together.

**FIGURE 10-1** ■ *An analysis of a simple English sentence. As this example shows, verbal language has a hierarchical structure. At the base of the hierarchy are the phonemes, which are units of vocal sound that do not, in themselves, have meaning. The smallest units of meaning in a language are morphemes, which include not only root words but such meaning-carrying units as the past tense suffix -ed and the plural -s. Complex rules of syntax govern how the words constructed from morphemes may be combined into phrases, and phrases into meaningful statements, or sentences.*


Sentence
The strangers talked to the players
Phrase
The strangers
talked to the players
Word
The
strangers
talked
to
the
players
Morpheme
The
strange
er
s
talk
ed
to
the
play
er
s
Phoneme
ð ə
streynj
ə r
z
t ə k
t
t u w
ð ə
p l e y
ə r
z

We will repeatedly encounter the idea of different linguistic rules (such as phonological rules or syntactic rules) in this section. These rules make up the *grammar* of the language and, taken together, define the way a language works. It is important that linguists and psychologists use the term *grammar* in a very restricted sense here, meaning "the set of rules for a language." In particular, *grammatical* in this context has nothing to do with the "rules" of "good English" such as "Don't use *ain't*" or "Use end punctuation at the end of a complete statement." To a linguist or a psycholinguist, the sentence "I ain't going to happily do it" is perfectly meaningful and "legal"—that is, it follows the "rules" of English that native speakers observe—and is therefore grammatical. (You understand it perfectly well, right?) Here *grammar* refers not to polite ways of speaking but to ways of speaking that form intelligible phrases or utterances recognizable as examples of language that a native speaker of the language might produce.

Linguists and psychologists distinguish between people's explicit and implicit knowledge of linguistic rules. It is doubtful, for instance, that most of us could state with precision or accuracy just what the rules for English syntax are. (If it were easy, many linguists would be out of a job!) Still, most of us can easily and almost immediately detect violations of the rules—for example, syntactically ill-formed sentences such as "Ran the dog street down cat after yellow the very the." Moreover, not only would we recognize the example as ungrammatical, but we would never produce such gross violations (although we frequently produce sentences with minor grammatical violations). Our knowledge of the rules is therefore not explicit (we cannot articulate what all the rules are, nor are we consciously aware of all of them) but implicit (whatever the rules are, we somehow follow them). We can often articulate the so-called prescriptive rules (such as "Don't say *ain't*"), which tell us how we *should* talk or write, even though we may violate them (for instance, whenever we actually say *ain't*). In contrast, we find it hard to articulate the descriptive rules of English, which characterize which sentences are legal and which are not.

Linguists and psychologists also distinguish **linguistic competence** from **linguistic performance.** The term *competence* refers to the underlying linguistic knowledge that lets people produce and comprehend their language. Competence is not always fully evident in actual use or performance of language. Lapses of attention or memory, nervousness or tiredness, environmental changes, shifts in interest, and random error can all interfere with our use of language, causing us to produce ungrammatical sentences or to comprehend a sentence incorrectly. Linguistic performance would reflect linguistic competence only under completely ideal conditions (Chomsky, 1965). In real life, such ideal conditions are never achieved. So if you overhear an ungrammatical utterance, it is probably not that the speaker's linguistic knowledge (competence) is faulty (especially if he is speaking in his native language) but rather that various other factors and pressures in his life at the time he spoke (performance) caused the error or errors.

## Phonology

To me, French sounds musical and German sounds harsh. No doubt, you too would describe various languages with various adjectives. Part of what distinguishes languages is their idiosyncratic sounds. Here we will consider the sounds of language (in our case, English) and how they are combined. We will draw on findings from two disciplines: **phonetics,** the study of speech sounds and how they are produced, and **phonology,** the study of the systematic ways in which speech sounds are combined and altered in language.

The English language has about 40 phonetic segments (sometimes called *phones*). Although a language may have a large number of phones, only certain ones are "meaningful" to it. Linguists use the term *phoneme* to refer to the smallest unit of sound that makes a meaningful difference in a given language. So if one phoneme in a word is exchanged for another, the word itself is changed. Thus if the phoneme \d\ is replaced with the phoneme \t\ the word *duck* becomes *tuck*. In English, we distinguish between the \l\ and the \r\ sound; other languages, such as the Cantonese dialect of Chinese, do not. Some of the dialect jokes about a Chinese speaker's saying "flied lice" instead of "fried rice" are based on the fact that a native speaker of Cantonese dialect simply wouldn't hear the difference (Fromkin & Rodman, 1974). Of course, other languages make sound distinctions that English doesn't, and native English speakers learning those languages can make errors that are just as ridiculed by the native speakers. Table 10-1 presents a list of English phonemes.

### Table 10-1 Examples of Some English-Language Phonemes

| *Symbol* | *Examples* |
|---|---|
| p | **p**at, a**pp**le |
| b | **b**at, am**b**le |
| d | **d**ip, love**d** |
| g | **g**uard, o**g**re |
| f | **f**at, **ph**ilosophy |
| s | **s**ap, pa**ss**, pea**c**e |
| z | **z**ip, pad**s**, **x**ylophone |
| y | **y**ou, ba**y**, f**e**ud |
| w | **w**itch, q**u**een |
| l | **l**eaf, pa**l**ace |
| ē | b**ee**t, b**ea**t, bel**ie**ve |
| e | **a**te, b**ai**t, **ei**ght |
| i | b**i**t, **i**njury |
| u | b**oo**t, tw**o**, thr**ou**gh |
| U | p**u**t, f**oo**t, c**ou**ld |
| oy | b**oy**, d**oi**ly |
| ay | b**i**te, s**igh**t, **i**sland |
| š | **sh**oe, mu**sh**, deduc**ti**on |

**Source:** Adapted from Moates and Schumacher (1980).

Linguists and phoneticians distinguish between consonants and vowels. Vowels work without obstructing the airflow, simply depending on the shape and position of the tongue and lips (Halle, 1990). Try articulating vowel sounds, and observe how your mouth changes configurations as you do.

Consonants are more complicated. In general, they are phonemes made by closing, or at least almost closing, part of the mouth. They differ first in what linguists call "place of articulation," meaning where the obstruction of the airflow occurs. For example, the \b\ and \p\ sounds are made by closing the lips, and the \s\ and \z\ sounds are made by placing the tongue against the hard palate of the roof of the mouth, just behind the ridge of gums. Consonants differ also in "manner of articulation," the mechanics of how the airflow is obstructed. The \m\ sound, for example, is made by closing the mouth while opening the nasal cavity; the \f\ sound is made through an obstruction of the airflow, producing a hissing sound. A third distinction between groups of consonants is known as *voicing*. Compare the \s\ in the syllable "sa" with the \z\ in "za." The \s\ does not require the vocal cords to be vibrated as the \z\ does; therefore, the \z\ is said to be voiced and the \s\ unvoiced.

Features of phonemes, such as those just reviewed, are involved in certain *phonological rules* that govern the ways in which phonemes can be combined. For example, if two "true" consonants (that is, all the consonants except \h\, \w\, \y\, \r\ or \l\ plus certain other sounds, such as the \th\ in *thy,* the \th\ in *thigh,* and the \ch\ in *chip*) are at the beginning of an English word, then the first must be an \s\ (Clark & Clark, 1977). This rule prevents word strings such as *dtop* or *mkeech* from being "legal" words in our language (although they may be so in other languages), whereas *stop* and *speech* are.

These phonological rules also explain how to pronounce new words and how to pronounce prefixes and suffixes to words, such as plural or past-tense endings. To illustrate, the way to form a plural for an English word depends on the phoneme with which the singular form of the word ends. From work in phonetics, we can state the following rule (after Halle, 1990):

| *If the Word Ends With* | *The Plural Ending of the Word Is* | *Examples* |
|---|---|---|
| \s z c j\ | \z\ | places, porches, cabbages |
| \p t k f \ | \s\ | lips, lists, telegraphs |
| Anything else | \z\ | clubs, herds, phonemes |

Different languages have different phonological rules; hence there are two answers to the question, Why do different languages sound different? One answer is that they contain different sounds (phonemes). A second answer is that they have different rules for combining those sounds (phonology).

## Syntax

The term *syntax* refers to the arrangement of words within sentences or, more broadly, to the *structure* of sentences—their parts and the way the parts are put together. Syntactic rules, similar to phonological rules, govern the ways in which different words or larger phrases can be combined to form "legal" sentences in the language. Thus sentences such as "The book fell off the table" are clearly acceptable to English speakers, and word strings such as "Chair the on sits man" are not. Syntactic rules should meet two requirements: They should be able to describe every “legal” sentence, and they should never be able to describe an “illegal” sentence (Chomsky, 1957).

What does it mean to say that sentences have structure? Consider the following sentence:

(1) The poodle will chase the red ball.

If you were to try to divide the words of this sentence into groups (linguists call these *constituents*), you might proceed as follows. Certainly the word *poodle* goes with the word *the*. Similarly, *red* appears to modify *ball*, and *the* forms another constituent with *red ball*. *Chase* could also form a constituent with *the red ball*, and *will* seems to modify this larger grouping. Notice that there are various levels of groupings or constituents, as depicted in Figure 10-2(A). This kind of diagram is called a *tree diagram*, and the small gray circles, called *nodes*, depict the various constituents of the sentence. Notice also that each word is a constituent by itself but that there are higher-level constituents as well, made out of different word groupings. So the word *ball* is a member of four constituents: [ball]; [the red ball]; [chase the red ball]; and [The poodle will chase the red ball].

**FIGURE 10-2** ■ *Tree diagrams of Sentence 1.*

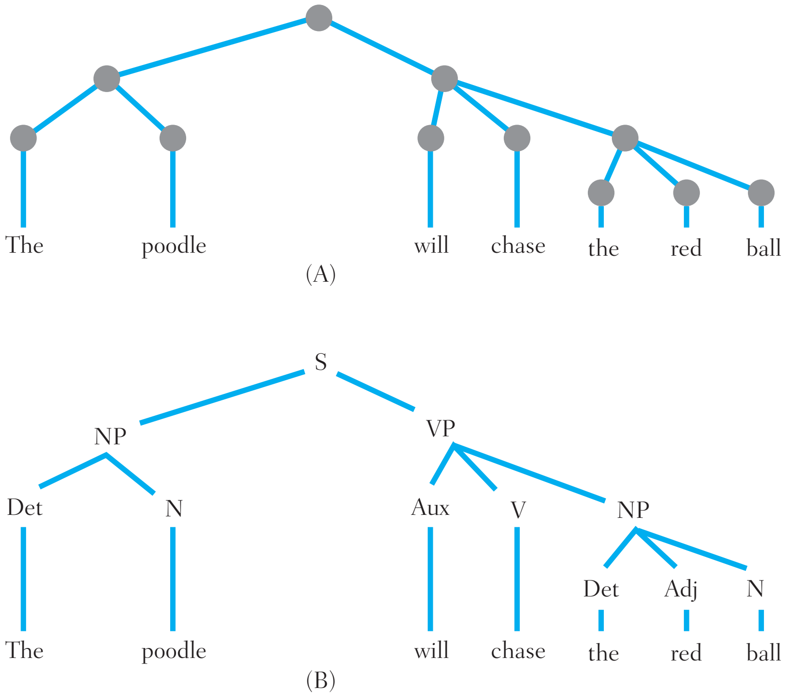


Figure 10-2(B) shows a similar diagram of the sentence, but here labels that tell the type, or category, of each constituent have replaced the gray dots. At the very bottom level in the tree, you'll see labels for familiar terms: V for verb, N for noun, Adj for adjective, and so forth. The labels give us some idea of the role that each word plays in the sentence and allow us to see that, generally speaking, if we replace a noun with another noun, we will still have a syntactically grammatical sentence. So, substituting *shoe* for *ball* gives us "The poodle will chase the red shoe." Higher up in the tree, other labels categorize the larger constituents. Thus the constituents "the poodle" and "the red ball" are both noun phrases (NP). The labeling is meant to capture our intuition that these constituents are similar to other constituents, such as "the angry fireman," "her grandfather's birthday," or "my first tooth." Figure 10-2(B) is called a *labeled tree diagram,* and it depicts what is called the *categorical constituent structure* of the sentence.

Notice that one noun phrase (NP) can be substituted for another in a sentence, yielding a sentence that is semantically anomalous (its meaning, if any, is hard to determine) but syntactically grammatical. So we could substitute the NP "my first tooth" for "the poodle" in Sentence 1 and get "My first tooth chased the red ball," an odd but certainly "legal" sentence.

What's the point of such diagrams? For one thing, they help explain why certain kinds of changes can be made in a sentence and others can't. One illustration comes from a change called *preposing*—taking a certain part of a sentence and moving it to the front, usually for emphasis (Radford, 1988). In the following examples, the italicized material has been preposed:

(2) *My naughty dog,* I'm mad at.

(3) *That inflated price,* I will not pay.

(4) *Up the mountain,* the hikers climbed furiously.

Preposing works (results in a grammatical or legal sentence) only when certain kinds of whole phrases or constituents are moved to the front. Thus it isn't legal to say, "Naughty dog, I'm mad at my," "Price, I will not pay that inflated," or "Mountain, the hikers climbed furiously up the." Tree diagrams such as the ones in Figure 10-2 provide answers to which parts of the sentence form constituents and are therefore candidates for preposing.

It is interesting that this kind of analysis of sentences explains an apparent paradox. The following four sentences are all "legal":

(5) Susan rang up Jodie.

(6) Martha stood up her blind date.

(7) Adrian looked up the number.

(8) Aristophanes ran up the mountain.

Preposing the phrase “up the mountain” can result in a legal sentence:

(8a) Up the mountain, Aristophanes ran.

But none of the other sentences can undergo preposing in this way, as the following illegal sentences (marked with asterisks) show:

(5a) *Up Jodie, Susan rang.

(6a) *Up her blind date, Martha stood.

(7a) *Up the number, Adrian looked.

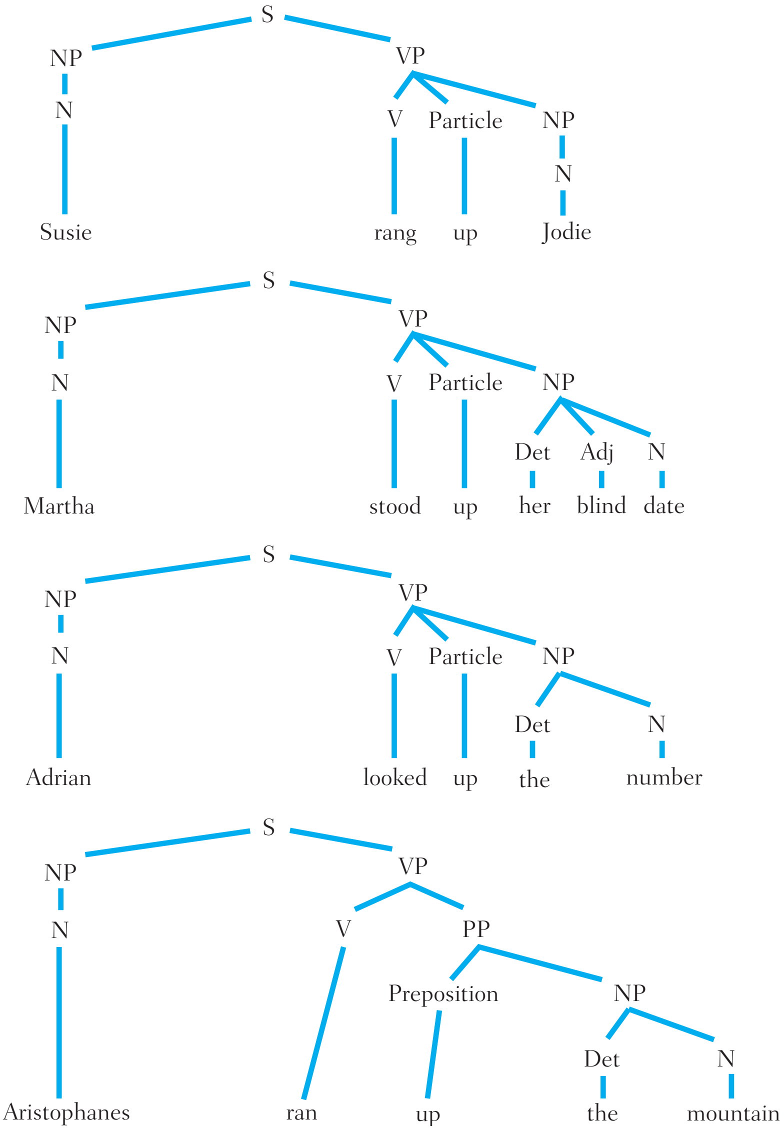
Figure 10-3 provides tree diagrams of Sentences 5 through 8 and shows that in Sentences 5 through 7, the word *up* is part of the constituent involving the verb and hence must stay with the verb in the sentence. However, in Sentence 8, the word *up* is a part of the constituent “up the mountain,” so it is perfectly acceptable to prepose it as long as the entire constituent gets moved.

How can we concisely summarize this discussion of what can and can’t be legally preposed? Linguists do so by formulating constraints on syntactic rules like this: Only constituents labeled as being whole phrases—for example, nodes marked as NP or VP (verb phrase)—can undergo movement from one position in a sentence to another. Such rules describe the ways in which parts of sentences are formed and work together.

Various linguists have proposed a variety of syntactic rules, as well as a variety of *kinds* of syntactic rules. For example, Chomsky (1965) proposed one set of rules, called *phrase structure rules,* that function to generate the structures depicted in tree diagrams such as Figures 10-2 and 10-3. These rules, sometimes called *rewrite rules,* describe the ways in which certain symbols can be rewritten as other symbols. The rule S → NP VP says that a symbol S (which stands for “sentence”) consists of different constituents and can be rewritten as the symbol NP (the symbol for the constituent “noun phrase”) followed by the symbol VP (the symbol for the constituent “verb phrase”). The point is that phrase structure rules allow certain symbols to be rewritten as other symbols. To rewrite a symbol with an actual word in the English language (for example, N → poodle) requires a different type of syntactic rule, a *lexical-insertion rule,* which allows the insertion of words (linguists call these *lexical items*) into the structures generated by the phrase structure rules.

Another type of syntactic rule is a *transformational rule.* Transformational rules turn structures such as those depicted in tree diagrams into other structures. Preposing phrasal constituents, for example, might be allowed through a transformational rule. Even a brief explanation of these or other syntactic rules, or other proposals for what the rules could be, would take us far afield (interested readers are referred to an introductory linguistics course or to Cowper, 1992). The point here is to show that just as the sounds of a language are organized and rule-governed in the way they are combined, so too are phrases and sentences.

**FIGURE 10-3** ■ *Tree diagrams of Sentences 5 through 8.*


S
NP
VP
N
V
Particle
NP
N
Susie
rang
up
Jodie
S
NP
VP
N
V
Particle
NP
Det
Adj
N
Martha
stood
up
her
blind
date
S
NP
VP
N
V
Particle
NP
Det
N
Adrian
looked
up
the
number
S
NP
VP
N
V
PP
Preposition
NP
Det
N
Aristophanes
ran
up
the
mountain

Again, rules of syntax, like rules of phonology, are probably not rules you are consciously aware of. However, the evidence accumulated by linguists and psycholinguists strongly suggests that you have some access to these rules, because your language behavior indicates a great deal of compliance with them and your judgments of grammaticality (under reasonable conditions) are remarkably consistent.

## Semantics

Semantics, the study of meaning, also plays an important role in our language use. After all, the sounds we produce are meant to communicate ideas, and for communication to take place, the listener (or audience) must somehow receive the speaker's (or sender's) meaning. The task of creating a complete theory of meaning is daunting and currently unfinished. Many of these topics relate to ones we covered in Chapters 7 and 8, so what we will cover here will be theories of meaning narrowly defined.

Theories of meaning have to explain several things, at a minimum (Bierwisch, 1970):

- *Anomaly* (Why can't one really say things like "Coffee ice cream can take dictation"?)
- *Self-contradiction* (Why is it contradictory to say, "My dog is not an animal"?)
- *Ambiguity* (Why isn't it clear where I intend to go in "I need to go to the bank"—to a financial institution or to the side of a river?)
- *Synonymy* (Why does "The rabbit is not old enough" mean the same thing as "The rabbit is too young"?)
- *Entailment* (Why does "Pat is my uncle" mean that Pat is male?)

Such theories should also explain how we use word meanings to process whole sentences and discourses. Much of cognitive psychologists' interest in semantics has to do with how knowledge is organized and stored and theories of how people form concepts and categorize things accordingly, topics we discussed in Chapters 7 and 8, respectively.

Let's examine how semantics enters into our understanding of a sentence. Consider the sentence "Sara exchanged a dress for a suit." Generally, we interpret this to mean that Sara took her dress somewhere (most likely, to the store where she had bought it) and gave it to someone (probably a salesperson), and in return that person gave Sara a suit. Exchanging thus seems to have something to do with two people, each giving something to the other, although *mutual giving* and *exchanging* are not defined as precisely the same thing (Miller & Johnson-Laird, 1976). What exactly does *exchanging* mean? Miller and Johnson-Laird (p. 577) offered the following definition: Someone, *X*, "exchanges" something, *w*, for something, *z*, with someone, *Y*, if two conditions are met: (1) *X* gives *w* to *Y* and (2) this obligates *Y* to give *z* to *X*. Notice that this analysis explains why exchanging and mutual giving are similar but not identical: Exchanging creates an *obligation* for *Y* to give something back to *X*, although *Y* might renege on the deal; in mutual giving, *X* and *Y* must give something to each other.

For listeners to figure out the meaning of a sentence, they need to pay attention to more than just the meanings of individual words. Syntax also gives clues as to what a sentence means. Were this not the case, the following two sentences, because they make use of the same words, would mean exactly the same thing:

(9) The professor failed the student.
(10) The student failed the professor.

Clearly, the meaning of *failed* in the two sentences is not identical. Something in the way words are arranged, then, must cue the listener or reader about who the actor of the sentence is, what the action is, and to whom or what the action is done.

The study of semantics also involves the study of *truth conditions* of sentences and of the relationships between sentences. As the term itself suggests, truth conditions are simply the circumstances that make something true. Refer to our earlier example sentence, "Sara exchanged a dress for a suit." Under what circumstances would this sentence be true? First of all, Sara has to be the person either actually carrying out the exchange or causing the exchange to happen (perhaps she sends Jane, her personal assistant, to the store). Second, Sara must, at the beginning of the transaction, have a dress to give and must give it to someone who gives her back a suit. If Sara gets back a hat instead of a suit, or gives a skirt rather than a dress, then the sentence is false. The point here is that our understanding of the meaning of this sentence requires (a) an understanding of the meaning of each word in the sentence, (b) an understanding of the syntax of the sentence, and (c) an understanding of the truth conditions of the sentence.

## Pragmatics

To communicate verbally with another speaker of the English language, you must produce utterances that follow rules of phonology, syntax, and semantics. In addition, a fourth set of rules must be honored if you want to communicate successfully. Known as *pragmatics,* these rules are the social rules of language; they include certain etiquette conventions, such as not interrupting another speaker and beginning conversations with certain conventional greetings (such as "Hi. How are you?").

Searle (1979) pointed out that in listening to another person, we must understand not only the sounds, words, and structure of the utterances but also the kinds of utterances. Different kinds of utterances demand different responses from us. For instance, in *assertives* the speaker asserts her or his belief in some proposition—for example, "It's hot in here" or "I'm a Libra."

These require little overt response from the listener, who is assumed to add the information asserted by the speaker into her or his own model of the world. *Directives,* another kind of speech act, are instructions from the speaker to the listener—for example, “Close the door” or “Don’t believe everything you hear.” *Commissives* are utterances that commit the speaker to some later action—for example, “I promise to clean my room” or “I guarantee this will work.” *Expressives* describe psychological states of the speaker—for example, “I apologize for eating the last piece of pie” or “I thank you for the favor you did for me.” Finally, *declarations* are speech acts in which the utterance is itself the action. Examples include “I now pronounce you husband and wife” or “You’re fired.” According to Searle’s *speech act theory,* part of our job as listeners is to figure out which of the five types a particular utterance is and to respond appropriately.

Moreover, there are usually a number of distinct ways of stating or asking something. Imagine, for instance, that you are sitting in a room and a cold breeze is blowing through an open window. You want the window closed, but for one reason or another you do not wish to close it yourself. What could you say to someone else to get him or her to close the window? Here are a few possibilities (all of which would be classified as directives in Searle’s, 1979, classification): (a) “Close the window”; (b) “Could you close the window, please?”; (c) “Hey, would you mind if we closed the window?”; (d) “I’m getting cold”; or (e) “Gee, there’s quite a breeze today, isn’t there?” How are you to choose among these (or other) options?

Note that in this example, how you choose to make your request will no doubt depend on whom you are talking to and where the conversation takes place (say, to your child in your house versus to your host in his house). Option (e), for instance, might be too subtle to communicate your intention if you were speaking to a preschooler (who might take it as a general and rather uninteresting comment on the weather). However, (a) might communicate clearly but mark you as an overbearing and rude guest if you were to say this to your host while dining at his house.

Gibbs (1986) studied the ways in which adults choose to frame requests. His data suggest that speakers anticipate the potential obstacles their listeners face in fulfilling a request and formulate it accordingly. For instance, imagine you are working in the library when your pen runs out of ink. You don’t have a backup, so you look around for someone from whom to borrow a pen. You don’t know the student at the next table, and he is engrossed, but he is the only person in sight, and he has two extra pens next to his books and papers. Would you say (a) “I need a pen,” (b) “Please give me a pen,” (c) “Excuse me, would you mind lending me a pen?” or (d) “Do you have an extra pen?” Gibbs’s participants, given similar scenarios, chose (c), responding to the biggest perceived obstacle of imposing on a stranger. A not-so-good choice would be (d), if you could see the extra pens, but it might be appropriate if you didn't know whether the student had extra pens with him.

Pragmatic understanding is something often exploited by advertising as well. Consider a television commercial for a new product, Eradicold cold pills. The video shows athletic, healthy looking people vigorously skiing, sledding, skating, and generally wending their way through a snow-covered winter wonderland. The voice-over says, "Aren't you tired of sniffles and runny noses all winter? Tired of always feeling less than your best? Get through a whole winter without colds. Take Eradicold Pills as directed." Odds are, you would draw the inference that taking Eradicold as directed would cause you to evade colds all winter. But the ad doesn't directly say that. Advertisers rely on the fact that the way they word ads implies causal relationships that may or may not be true. Harris (1977), who studied comprehension of such ads, showed that people are not very good at distinguishing between what an ad directly states and what it only implies.

So far, we've seen that our language is structured and rule-governed at several different but interacting levels. Although much more can be said about each of these levels (each of which gives rise to several linguistics courses), we need to turn our attention to how the structure of language directs and is influenced by other kinds of cognitive processing. We'll look first at how speakers of a language process incoming utterances or written sentences to comprehend their meaning.

## ■ LANGUAGE COMPREHENSION AND PRODUCTION

Like other information, language must be transformed from raw input into meaningful representations. One of the first stages of this transformation is perceptual. In this section, we'll examine the perception of speech, noticing the special ways in which speech input is initially processed. We will then turn to further stages of processing—in particular, comprehension and the processing of discourse, such as conversations. Finally, we will examine the processing of written language through reading.

### Speech Perception

One way we encounter and use language is in the form of speech. Understanding the speech of someone talking to you is usually quite easy unless it is in a foreign language or the speaker has a very marked speech impediment. We can almost always understand the speech of children, adults, fluent speakers, and those with strong foreign or regional accents. As we will see, this ability is pretty remarkable.

It might seem reasonable to suppose we perceive speech in the way (we think) we perceive written text: one sound at a time, using the pauses between sounds (like the white space between letters) to identify letters and the pauses between words to identify when one word ends and another begins. Unfortunately, this tidy explanation doesn't work. (Actually, evidence suggests we really don't process written text letter by letter, either.)

George Miller (1990) described two fundamental problems in speech perception. First, speech is continuous. Rarely are there pauses around each sound; different sounds from the same word blend into each other. This is shown most clearly in Figure 10-4, which displays a spectrogram of a spoken sentence. A spectrogram is a graphic representation of speech, showing the frequencies of sound, in hertz (cycles per second), along the *y* axis, plotted against time on the *x* axis. Darker regions in the figure indicate the intensity of each sound at each frequency. Note that the boundaries (white spaces) do not correspond to word or syllable boundaries. Indeed, nothing in the physical stimulus itself indicates where these boundaries are. In other words, when you listen to someone talk, it sounds as if there were pauses between syllables and words, but many of those pauses are illusory!

A second problem in speech perception is that a single phoneme sounds different, depending on context. Although it casually appears as if *baby, boondoggle,* and *bunny* all began with the same identical sound, this is not the case.

**FIGURE 10-4** ■ *Spectrogram of a person pronouncing the indicated sentence.*

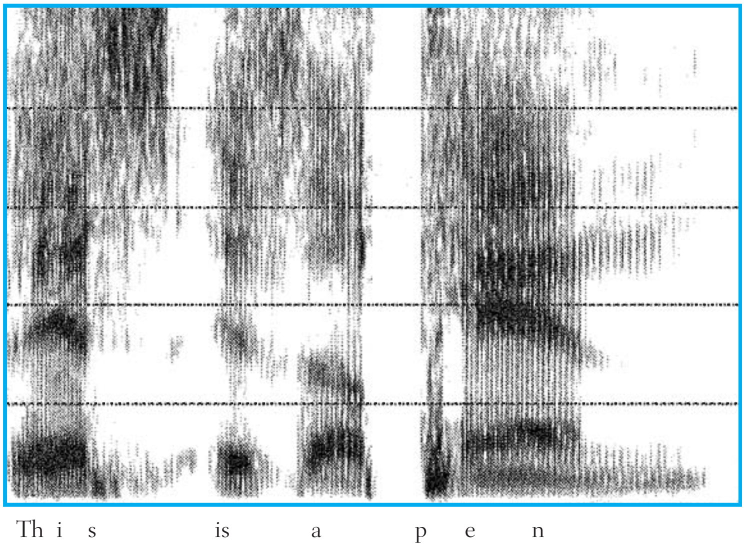
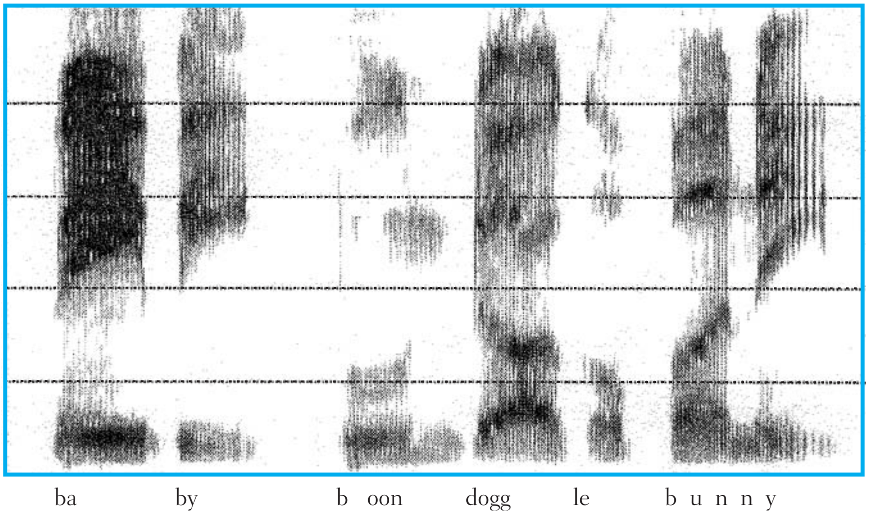


Figure 10-5 presents a spectrogram of my pronouncing these three words, and examination of the spectrogram reveals few if any properties present for all three words. Moreover, men and women generally speak with different pitches (women's voices generally having higher pitch, or frequencies), different people have different accents, and speakers talk differently when shouting, coaxing, whispering, or lecturing. Thus you can realize just how complicated it is to ascertain which phoneme is being produced simply from the physical properties of the acoustic stimulus.

**FIGURE 10-5** ■ *Spectrogram of the words* baby, boondoggle, *and* bunny.



Given these problems, how do most of us manage to perceive speech rather easily? In part, the answer is that we seem to come specially equipped to perceive speech in efficient ways. Although the actual acoustic stimulus can vary infinitely in its phonetic properties, our perception of speech sounds is *categorical:* In processing speech sounds, we automatically, without awareness or intention, force the sounds into discrete categories.

Lisker and Abramson (1970) demonstrated the categorical perception of speech sounds. They used a computer to generate artificial speech sounds consisting of a bilabial stop consonant (which sounds like either a \b\ or a \p\ sound) followed by an "ah" sound. The \b\ and \p\ sounds have the same consonantal features and differ only in voice onset time. (Voice onset time, or VOT, has to do with how quickly after the consonant sound is released the vocal folds begin to vibrate; negative values of VOT indicate the vocal cords begin to vibrate *before* the sound is released.) Lisker and Abramson varied the VOT, by computer, from −0.15 second to +0.15 second, generating 31 syllables.

When they presented the syllables to listeners, the listeners "heard" only two sounds: a "ba" and a "pa." Any syllable with a VOT of +0.03 second or less was heard as a "ba," and any syllable with a VOT of more than +0.03 second was heard as a "pa." Participants did not report differences in the sounds of the syllables that were on the same side of the boundary. To them, a syllable with a VOT of −0.10 second was indistinguishable from a syllable with a VOT of −0.05 second. However, two syllables that were just as close in VOTs but fell on opposite sides of the boundary (such as 0.00 and +0.05) were identified by 100% of the participants as being different sounds: a "ba" sound and a "pa" sound, respectively.

Apparently, then, we pay attention to certain acoustic properties of speech (those that make a meaningful difference in our language) but ignore others. This might explain why we can understand the speech of a stranger (who speaks our language) quickly and effortlessly: We ignore the differences in his or her speech (pitch of voice, accent) that are not meaningful. Incidentally, categorical perception has also been demonstrated for some nonspeech sounds, such as tones, buzzes, and musical notes played on different instruments (Harnad, 1987). Moreover, studies of infants have shown that although very young infants can discriminate many, if not all, of the sound distinctions used in all the world's languages, that ability begins to narrow to just the phonemes in the infant's primary language when the infant is about 6 months of age (Eimas, 1985).

Although we clearly pay careful attention to critical sound distinctions in our language, it isn't just sounds that influence us. A clever study by Massaro and Cohen (1983) demonstrated that we also make use of visual information in the perception of speech. These investigators examined the categorical perception of the stop consonants \b\ and \d\, two sounds that differ only in the place of articulation. Participants heard nine computer-synthesized syllables that ranged in their acoustic properties from a clear "ba" sound to a clear "da" sound. In the "neutral" condition, participants heard the syllables with no visual information. In two other conditions, participants heard the syllables while watching a silent but synchronized videotape of a speaker who was pronouncing either "ba" or "da." One question was whether participants would notice a discrepancy when the auditory information presented was "ba" but the videotaped speaker was saying "da." The participants did not. It is interesting, however, that what the speaker appeared to be saying influenced what was heard: Syllables in the middle of the "ba"–"da" continuum were perceived slightly differently as a function of what the speaker appeared to be saying relative to the perception reported in the neutral condition.

Apparently, then, visual cues affect how sounds are perceived. One might describe this as a kind of *context effect,* first described in Chapter 3. A number of other studies have demonstrated that speech perception is subject to a number of other context effects. Studies by Warren and his collaborators (Warren, 1970; Warren & Obusek, 1971) have demonstrated that in some cases people "hear" phonemes that are not there! In the 1970 study, Warren presented participants with a recording of the sentence "The state governors met with their respective legi*latures convening in the capital city," in which a 120-millisecond portion had been replaced with a coughing sound (indicated by the asterisk). Only 1 of 20 listeners reported detecting a missing sound covered by a cough, and the one who did misreported its location. The other 19 demonstrated *phoneme restoration effect,* so called because listeners apparently "restore" the missing phonemes predicted by other linguistic information during the course of perception.

People are capable of using a great deal of information to "predict" what the correct sound of a missing segment should be. Warren and Warren (1970) demonstrated this by presenting people with one of four sentences. Each was the same recording, with the exception of the final word that had been spliced on, and each contained a missing segment, as indicated by an asterisk:

(11) It was found that the *eel was on the *axle*.

(12) It was found that the *eel was on the *shoe*.

(13) It was found that the *eel was on the *orange*.

(14) It was found that the *eel was on the *table*.

Depending on the sentence (which provided a context for the missing sound), participants reported hearing *wheel, heel, peel,* or *meal*. Here again, we see that the context directs the listener's perception of a sound—typically without the listener's even being aware of this influence.

Other studies also suggest that people use context to help them perceive speech. One study, by Marslen-Wilson and Welsh (1978), required participants to "shadow" speech—that is, to repeat it aloud. (We encountered shadowing tasks in Chapter 4, as you may recall.) The investigators introduced some distortions into the speech presented to participants (for example, the pseudoword *cigaresh*). They found participants were often likely to restore the distortion to the proper pronunciation (*cigarette*), especially if the word was highly predictable from the preceding context (for example, "Still, he wanted to smoke a ______"). This result suggests that readers and listeners typically use the context of the previous words in a sentence to predict the next word and can even "mishear" or "misread" that word if it is presented in a distorted fashion. You might note here a parallel to context effects in visual perception, a topic reviewed in Chapter 3.

In the last decade, a couple of companies I use (mostly airline and credit card) have installed voice recognition systems. So, for example, I can call a toll-free number and check my credit card balance, or receive flight departure and arrival information, simply by speaking the numbers of the card or flight clearly into the phone. If speech recognition is so complicated, you might wonder, how come a computer can do it?

The answer parallels that for handwriting recognition systems, as we discussed in Chapter 3. Simply put, the incoming stimuli are limited to a number of discrete categories. The voice recognition systems really only recognize names of different digits. They don't have to figure out which language I'm speaking in (they only work in one or two languages, and I specify that at the beginning of the call), and they expect only certain responses "one" or "two" or "three" but not "zebra" or "melting pot" or "hurricane."

## Speech Errors in Production

So far, we have examined the ways in which we perceive language, specifically spoken sounds, but this is only part of the story regarding the ways in which we process speech. As native speakers of a language, we do more than comprehend and process it—we also produce speech for others to comprehend and process. One kind of study of speech production focuses on *speech errors,* defined as instances in which what the speaker intended to say is quite clear, but the speaker makes some substitution or reorders the elements. Some examples of speech errors are the following (adapted from Garrett, 1990):

(15) Sue keeps food in her *v*esk. (Substitution of "v" for "d")

(16) Keep your cotton-pickin' hands off my weet *s*peas. (Shift of "s")

(17) . . . got a lot of po*ns* and pa*ts* to wash. (Exchange of sounds)

(18) We'll sit around the *song* and sing *fires.* (Exchange of words and morphemes)

Much of the data from speech error studies is observational rather than experimental, for the simple reason that it seems to be difficult to control experimentally the ways in which people produce speech. Because of the observational nature of the studies, assertions about causation are problematic. However, one can look at the relative frequency of occurrence of different kinds of errors and make inferences regarding the underlying mechanisms. Garrett (1990) advocated this approach.

In studying one kind of speech error, word substitution, Garrett (1988) found two broad classes: errors that showed meaning relations (for example, using *finger* in place of *toe,* or *walk* instead of *run*) and errors that showed form relations (for example, *guest* instead of *goat, mushroom* for *mustache*). Garrett argued that the two kinds of errors were very distinct: Those that showed similarities of meaning rarely involved similarities of form, and vice versa. Although such errors are possible (such as *head* for *hair, lobster* for *oyster*), they seldom occur.

According to Garrett (1990), the relative infrequency of word substitution errors showing *both* meaning and form similarities indicates the language production system processes information about meaning and information about form at different points in sentence construction. His reasoning: If meaning and form processes operate simultaneously, then sentences in which both kinds of similarity are present ought to produce the most errors because there is greater opportunity for error to come about. This doesn't happen, suggesting that the two kinds of processing are separate and operate at different points.

## Sentence Comprehension

How do people understand or recover the meaning from sentences? It is a complicated task and, as we have seen, requires us to retrieve not only the meaning of individual words but also syntactic structure. Much evidence suggests people pay attention to syntactic constituents, such as those described earlier.

In a series of studies, Jarvella (1971) had people listen to long passages of speech. Interruptions during the passages were cues to the participants to recall, as precisely as possible, whatever they could from the sentence just heard. Jarvella created passages that contained identical phrases, except that the phrases "belonged" to different clausal constituents. Consider Passages 19 and 20, and notice that the middle clauses in each are the same, although they belong to different sentences:

(19) With this possibility, Taylor left the capital. After he had returned to Manhattan, he explained the offer to his wife.

(20) Taylor did not reach a decision until after he had returned to Manhattan. He explained the offer to his wife.

Participants' recall for the initial clauses (the ones that differ in the two passages) was similar and averaged around 16% verbatim recall. Recall for the third clause ("he explained the offer to his wife") was similar for both groups of participants, averaging 85%, presumably because they were still actively processing this part of the sentence and were therefore still holding it in working memory. A more interesting result concerned the middle clause ("after he had returned to Manhattan"). It contained the same words and sounds but was part of the first sentence in Passage 20, and of the second sentence in Passage 19. Those listening to passages such as Passage 19 showed overall accuracy of about 54%, but those listening to Passage 20 only 20%, for the clause at issue. Jarvella (1971) argued that in Passage 19, the second clause is still being processed because the sentence is not yet finished; therefore, the clause is still in working memory. However, in Passage 20 the second clause belongs to a sentence for which processing is finished. (Work by Just and Carpenter, 1987,

## Box 10-1 Examples of Ambiguous Sentences

***Phonetic ambiguity***

Remember, a spoken sentence often contains many words not intended to be heard.
*Ream ember us poke can cent tense off in contains men knee words knot in ten did tube bee herd.*

***Lexical ambiguity***

I've got to go to the bank this morning.
I've got to go to First National this morning.

or

I've got to go to the river's edge this morning.

***Syntactic ambiguity***

Have the missionaries eaten.
(Spoken by the bishop as a question or spoken by a cannibal chief as an order)

**SOURCE:** Garrett (1990).

described in the next section, suggests that we don't always process sentences clause by clause.)

Ordinarily, it seems, when we finish processing a sentence, we "discard" the exact wording and store only a representation of its gist (Sachs, 1967). Apparently, then, some of the syntactic rules described earlier in this chapter are similar to those people ordinarily rely on as they interpret speech. Although people might never consciously think about the function of a word or phrase in a sentence, the evidence overwhelmingly suggests they are sensitive to it and use information about syntax as they understand.

Comprehending a sentence often involves resolving its possible ambiguities. Box 10-1 offers examples of phonetic, lexical (that is, word-level), and syntactic ambiguities present in different sentences. The interesting thing about the sentences is that we would ordinarily not notice the ambiguities; our processing would result in one unambiguous representation.

Only rarely, and with certain kinds of sentences, do we even notice ambiguities. Consider the following sentences (Garrett, 1990, p. 137):

(21) Fatty weighed 350 pounds of grapes.

(22) The cotton shirts are made from comes from Arizona.

(23) The horse raced past the barn fell.

These sentences are sometimes called *garden path sentences* because they lead the listener or reader down one path, to one interpretation, until somewhere in the middle or the end of processing, he or she realizes the interpretation is incorrect and the sentence must be reprocessed. Normal sentence processing somehow goes astray with these examples.

The three preceding sentences have initial fragments (such as "The cotton shirts are made from") that are *syntactically ambiguous:* They are consistent with at least two different parses. In this sentence, the word *cotton* could be treated as an adjective, modifying *shirts* (as in "The cotton shirts are made from dyed fibers"), or as a noun (as in "The cotton shirts are made from comes from Arizona"). Some have argued that we have a preference for parsing the fragment in certain ways. According to this line of thinking, we come to the second interpretation only when forced to because the first parse does not work. We notice that the first parse does not work only when we get to the fragment "comes from Arizona" and don't know what to do with it (Altmann, 1987).

A sentence processor encounters other ambiguities as well. One type is called **lexical ambiguity.** It occurs with words that have two meanings, such as *bank,* which can refer to either a financial institution or the edge of a river. How are lexical ambiguities normally resolved? A study by Swinney (1979) offers some insights.

Swinney (1979) presented people with spoken passages. Some of these contained ambiguous words; other, similar passages (heard by different experimental participants) did not. In each case, the unambiguous version included a word synonymous with one of the meanings of the ambiguous word. Here is an example of such a passage (with the ambiguous/unambiguous words italicized):

(24) Rumor had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several roaches, spiders, and other (*bugs/insects*) ‡ in the corner of his room. (Swinney, 1979, p. 650)

Simultaneously, people participated in a visual lexical decision task (we discussed such tasks in Chapter 7) in which they were presented with a string of letters and asked to decide, as quickly as possible, whether the string formed an English word. The letter strings were presented at the point marked with a double dagger ‡ in the preceding example. Previous work by Swinney and others had demonstrated the existence of priming across the modalities (that is, a spoken word can prime a visually presented word). Swinney's question here was, Would all the meanings (such as "insect," "recording device") of an ambiguous word (such as *bug*) be subject to priming, or would priming occur only for the meaning activated by the context?

Swinney's (1979) results suggested that even in highly biased contexts such as the preceding one, both meanings of an ambiguous word (in this case, *bug*) were able to prime performance in the lexical decision task if the visual presentation happened immediately after the auditory presentation of the ambiguous word. So, for example, Passage 24 primed both "spy" and "ant," which are semantically related to different meanings of the word *bug*, when they were presented immediately after the participants heard *bug*. If the visual presentation of letter strings was delayed for even as few as four syllables after the auditory presentation of the ambiguous word, however, priming occurred only for the contextually appropriate meaning of the ambiguous word. So, with a delayed presentation of words visually, the spoken word *bug* would prime "ant" but not "spy" in the context of Passage 24. Subsequent research by Gernsbacher (1993) supports Swinney's findings. Gernsbacher and her colleagues have shown that good readers suppress the inappropriate meaning of a word ("spy"), and use the appropriate meaning ("ant"), more efficiently and readily than do poor readers.

These results have several implications. First, when we process ambiguous sentences, all the meanings of an ambiguous word are temporarily available, through what looks to be an automatic, bottom-up process or set of processes. So however context effects operate, they do not operate immediately to restrict the listener or reader to the most appropriate "reading" of the words. Instead, for a period of time all meanings are accessible; however, the period is very short.

Three syllables after presentation of the ambiguous word (for most people, about 750 to 1,000 milliseconds), only one meaning remains active, suggesting that people resolve sentence ambiguity fairly quickly. Garrett (1990), reviewing these and other results, concluded that sentence comprehension normally occurs with left-to-right processing (each word in the sentence is processed sequentially), with each word normally processed once and normally one interpretation assigned. Processing results in each sentence's being assigned a "logical structure" so that the reader knows the role of each word in the sentence and how the sentence fits with preceding sentences. Garden path sentence, however, demonstrate that normal processing can sometimes fail. Still, the rarity of garden path sentences suggests that most of the time we process sentences very rapidly and efficiently.

## Comprehending Text Passages

We've just examined some evidence of how we process individual sentences. One question we can now ask is how processing of individual sentences works when they are bundled together into connected passages, such as paragraphs or stories. Much of the time, when we encounter text passages, they are in written form. Thus, to examine text processing, we will first need to review briefly some findings on how people read.

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*The language comprehension processes used in reading are complex but are often taken for granted.*

Just and Carpenter (1987) have conducted a number of studies on how people read. They often use computer-driven instruments to measure and record eye *fixations* on parts of the written text. Fixations are brief pauses that everyone makes as their eyes scan text. Reading consists of a series of fixations and jumps between fixations. The average fixation lasts about 250 milliseconds (about a quarter of a second); the average jump lasts 10 to 20 milliseconds (Just & Carpenter, 1987).

Just and Carpenter's model of reading assumes that as soon as readers encounter a new word, they try to interpret it and assign it a role. The authors called this the *immediacy assumption.* In addition, Just and Carpenter (1987) proposed what they called the *eye–mind hypothesis,* which holds that the interpretation of each word occurs during the time it is fixated. Therefore, the time spent on each fixation provides information about ease of interpretation. (Rayner and Sereno, 1994, gave reasons against both these assumptions or hypotheses, although these probably do not undermine the results reported next. Tanenhaus, Magnuson, Dahan, and Chambers, 2000, present a similar model

## Box 10-2 Gaze Durations of a Typical Reader

Eye fixations of a college student reading a scientific passage. Gazes within each sentence are sequentially numbered above the fixated words with the durations (in msec) indicated below the sequence number.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | 9 | 1 |
| 1566 | 267 | 400 | 83 | 267 | 617 | 767 | 450 | | 450 | 400 |
| Flywheels | are | one | of the | oldest | mechanical | devices | known | to | man. | Every |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 5 | 4 | 6 | 7 | 8 | | 9 | | 10 |
| 616 | 517 | 684 | 250 | 317 | 617 | 1116 | | 367 | | 467 |
| internal | combustion | engine | | contains | a small | flywheel | that | converts | the | jerky |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | 12 | | 13 | 14 | 15 | 16 | 17 | | 18 | 19 | 20 | 21 |
| 483 | | 450 | | 383 | 284 | 383 | 317 | 283 | | 533 | 50 | 366 | 566 |
| motion | of the | pistons | into | the | smooth | flow | of | energy | that | powers | the | drive | shaft. |

**SOURCE:** Just and Carpenter (1980, p. 330).

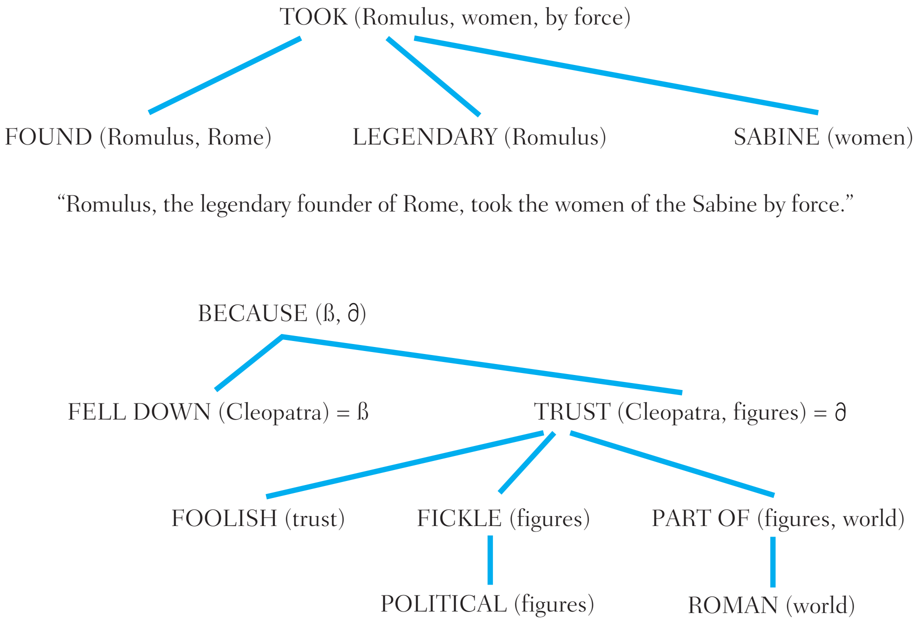
of eye movements that they believe indicate access of stored words from memory during spoken language comprehension.) Just and Carpenter argued that among the factors that increase fixation duration, and thus ease of interpretation, are word length, word infrequency, and syntactically or semantically anomalous words.

The researchers (Carpenter & Just, 1983; Just & Carpenter, 1980) presented college students with passages from magazines such as *Newsweek* and *Time* describing scientific inventions, technical innovations, or biological mechanisms. Box 10-2 shows sample results for one student. Numbers above each word indicate the fixation time (measured in milliseconds) for that word. Note that content words, such as *flywheels, devices,* or *engine,* almost always receive longer fixations than function words, such as *the, on,* or *a,* which often are not fixated at all. Although not every word is fixated, the content words almost always are. These results suggest that more time is spent on the meaningful or semantically rich parts of the text, as would be expected, given the reader's goal of understanding meaning.

Other research on reading also suggests that semantic factors influence the reading task. Kintsch and Keenan (1973) showed that two sentences of equal length might be differentially difficult to process. The source of the difficulty, they suggested, lies in the **propositional complexity** of the sentences, the number of basic ideas conveyed. The two sentences in Figure 10-6 are approximately equal in length, although they differ greatly in the number of underlying propositions, or basic ideas. This model predicts that the second sentence, having the

**FIGURE 10-6** ■ *Propositional structure of two sentences.*

**SOURCE:** Kintsch and Keenan (1973, p. 259).


TOOK (Romulus, women, by force)
FOUND (Romulus, Rome)
LEGENDARY (Romulus)
SABINE (women)
BECAUSE (ß, ∂)
FELL DOWN (Cleopatra) = ß
TRUST (Cleopatra, figures) = ∂
FOOLISH (trust)
FICKLE (figures)
PART OF (figures, world)
POLITICAL (figures)
ROMAN (world)

"Romulus, the legendary founder of Rome, took the women of the Sabine by force."

"Cleopatra's downfall lay in her foolish trust in the fickle political figures of the Roman world."

same number of words but more propositions than the first, will be more difficult to process, and indeed, this is what Kintsch and Keenan found.

Participants were asked to press a button after reading a sentence (or passage) silently and then to immediately recall as much of the sentence as they could. The more propositions a sentence contained, the longer it took for the participants to read and comprehend it. Further, they were much more likely to recall the more "central" propositions, those critical to the meaning of the sentence, than the more peripheral ones that merely elaborated on the central ideas. This result suggests that propositions are mentally represented in some sort of hierarchy, with more central propositions at the top of the hierarchy, as shown in Figure 10-6. The peripheral, lower-level propositions apparently serve the function of elaborating the more central propositions and so are less important to remember.

Another factor influencing the processing of text has to do with the relationships among sentences. How do people integrate related ideas that may come from different sentences? Haviland and Clark (1974) described what they called the *given–new* strategy, a pragmatic approach to processing sentences whereby listeners and readers divide sentences into two parts: the given and the new. The given part of a sentence contains information that is (or should be) familiar from the context, the preceding information (including other sentences just presented), or background knowledge. The new part, as the term implies, contains unfamiliar information. Listeners first search memory for information corresponding to the given information and then update memory by incorporating the new information, often as an elaboration of the given.

The given–new strategy can work only if the information in the given part of the sentence corresponds to some information in the listener's memory, called the *antecedent*. One way to help the listener make this connection is to use the same description in the given part of the sentence as in memory. However, as a practical matter, it is often easier to use slightly different ways of referring to things and to expect the listener to make some connections—the obvious ones—on his or her own. The connections, called *bridging inferences,* will naturally take some time to make.

In one experiment, Haviland and Clark (1974) presented people with passages consisting of context followed by target sentences. Sometimes (as in Passage 25) the target sentence had given information that exactly matched the antecedent information (from the context); other times, participants had to draw a bridging inference (as in Passage 26).

(25) We got some beer out of the car. The beer was warm.

(26) We checked the picnic supplies. The beer was warm.

As predicted, it took participants longer to read and comprehend the target sentence in Passage 26 than it did participants who read the same target sentence in Passage 25, presumably because those participants reading Passage 25 had to draw the bridging inference "The picnic supplies included beer."

Readers must sometimes also make inferences between sentences that are far apart in a text. Think about a mystery story, for example. To understand how the clues of a mystery fit together to create a solution, readers must infer how the central propositions from each clue connect to the essential ideas of another clue. These connections need to occur even though the clues may appear at different times in the story. Readers vary in the number of such inferences they can create at any one time, and the inferences themselves vary in how strongly they connect one piece of information to another. Researchers have consistently shown that the number of inferences readers make and the strength of the inferences create affect how well readers remember and understand what they read (Goldman & Varnhagen, 1986; Graesser & Clark, 1985; Trabasso, Secco, & van den Broek, 1984; Trabasso & van den Broek, 1985). In short, inferences of all types, including bridging inferences between sentences or inferences that tie more distant parts of a text together, are crucial to how well you or I understand what we read.

## Box 10-3 An Ambiguous Story

If the balloons popped, the sound wouldn't be able to carry since everything would be too far away from the correct floor. A closed window would also prevent the sound from carrying, since most buildings tend to be well insulated. Since the whole operation depends on a steady flow of electricity, a break in the middle of the wire would also cause problems. Of course, the fellow could shout, but the human voice is not loud enough to carry that far. An additional problem is that the string could break on the instrument. Then there could be no accompaniment to the message. It is clear that the best situation would involve less distance. Then there would be fewer potential problems. With face-to-face contact, the least number of things could go wrong.

**SOURCE:** Bransford and Johnson (1972, p. 718).

The role of context in processing language has been extensively documented by John Bransford and Marcia Johnson. Read the passage in Box 10-3, then cover it and try to recall as much as you can. If you are like Bransford and Johnson's (1972) participants, you may find the task very difficult, and your recall may include only a few of the ideas. However, if you were first provided with a context for the passage, such as the one depicted in Figure 10-7, your recall would be much more complete. Bransford and Johnson showed that with the context provided before the passage, participants recalled an average of 8.0 out of 14.0 distinct ideas. Without any context, or even with the context provided after the passage, participants only recalled about 3.6 ideas.

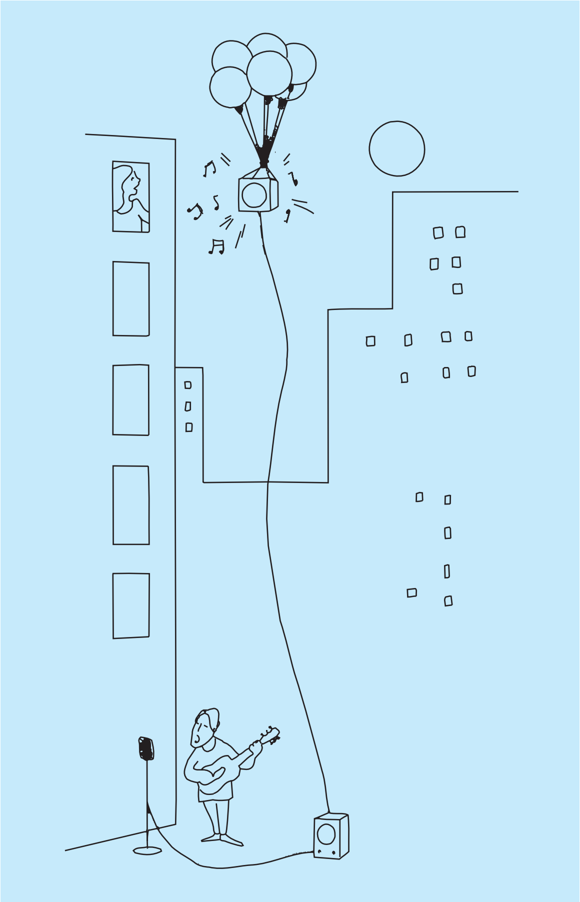
Two of my students, Kathryn Ainsworth and Rebecca Baumann (1995), extended this work in a study with college students, who were asked to read the two passages in Box 10-4. Do that yourself, before reading further.

Ainsworth and Baumann (1995) asked research participants to first read and then recall the passages. They found a gender difference in recall. Males recalled an average of 6.94 ideas (out of a possible 29) to females' 5.72 on the first passage. For the second passage, the reverse pattern was obtained: Females recalled 6.28 ideas (of a possible 34) to the males' 4.39. What accounts for this gender difference?

Ainsworth and Baumann (1995) attributed it to the participants' familiarity with the tasks being described: The first passage refers to tying a tie; the second, to braiding hair. You may note a connection here to the idea of schemata, discussed in Chapters 6 and 7. Recall that schemata are organized frameworks for representing knowledge that often function like scripts of a play, with characters, plots, and settings. You might think of the contexts that Bransford and

**FIGURE 10-7** ■ *Context for story in Box 10-3.*

**SOURCE:** Bransford and Johnson (1972, p. 717).



Johnson (1972) provided some of their participants as schemata. Their experimental results, then, show that schemata aid in the comprehension, and therefore the recall, of text passages.

Van den Broek and Gustafson (1999) offer three conclusions from research on reading texts. The first is that "the mental representation is a construction by the reader that differs from, and goes beyond, the information in the text itself" (p. 17), meaning that people recruit their own background knowledge to draw inferences to comprehend text. Second, "a good representation is coherent" (p. 18), implying that structures such as schemata or story grammars (see later) are used to make the information in a text fit together. A third principle, which we have seen evidence for in earlier chapters, is that a reader's attentional resources are limited. Therefore, to cut down on their workload, readers do not

## Box 10-4 Passages Used in Recall Study

***Passage 1***
This is a task you do not do everyday; it is reserved for semispecial to special occasions. You need to obtain two appropriate materials in spectacular condition; altering one may be necessary. Make sure the first item is secured almost to the top, but the top should remain loose. You have two parts of equal importance, but one is twice as much as the other. You place the bigger part over the little part and pull the bigger part through the "V," taking it down in front. Now you pull the top the opposite way from the bottom and the bottom from the top. Make sure it is secured and even. Finally, slide the bottom part through the loop in back. You might have to repeat the procedure if the parts result in equal length.

***Passage 2***
This is a good variation to your daily procedure and helps keep all the loose ends together. To start, make sure everything is orderly and no impediments exist. Sometimes this requires assistance, but with practice you can do it yourself. Begin with the top and front. There are three elements of near equality needed to begin the procedure. You take one element from one area and put it over the second element, pulling this under the one element, and do the same from the third element, adding more substance with each element. You have to continuously do this until you run out of substance. When almost finished, keep it tight to obtain neatness. The last part is extra bound; once hitting the base, use the initial three parts to wrap it up at your own preference.

**SOURCE:** Ainsworth and Baumann (1995). Reprinted with permission.

draw every logically possible inference they could from a text (the number of inferences drawn would be overwhelming). Instead, van den Broek and Gustafson posit, inferences are created only when they are needed to create coherence.

## Story Grammars

In Chapter 7, we encountered the idea of scripts, defined as schemata for routine events. Earlier in this chapter, we discussed the idea of grammars—systems of rules that result in legal entities, such as sentences. Some cognitive psychologists have put these two ideas together, forming the concept of a **story grammar** to describe the way people comprehend large, integrated pieces of text.

Story grammars are similar to scripts in that both have variables or slots that are filled in differently for different stories. For example, different stories have different protagonists, settings, plots, conflicts, and resolutions. Story grammars are also similar to syntactic grammars in that they help identify the units (constituents) and the role each unit plays in the story (Just & Carpenter, 1987). Like syntactic grammars, story grammars attempt to describe the hierarchical structure of the story, specifying how each part of the story relates to the other parts. Story grammars produce a division of (or parse) the story into parts or constituents. Text passages that cannot be parsed by a grammar are then seen as "illegal" or "ungrammatical" stories, just as strings of words that cannot be parsed by a syntactic grammar are identified as "ungrammatical" sentences.

Like other schemata, story grammars provide listeners or readers with a framework within which to expect certain elements and sequences, enabling them to fill in with "default values" things that are not explicitly stated. For example, young children expect stories to begin with some sort of setting, such as "Once upon a time" or "A long time ago." One example of a story grammar is shown in Table 10-2 (Thorndyke, 1977). It divides a story into several constituents: setting, theme, plot, resolution, and so forth. Each of these parts may also have subparts; for example, settings may have location, characters, and time. Some parts may also have a number of different instances of certain subparts; for example, the plot may have several episodes. The asterisks in the table indicate that certain subparts (such as "episode" in Rule 4) can be repeated an indefinite number of times. Parentheses around a subpart indicate that the subpart is optional.

**Table 10-2** Example of a Story Grammar

| *Rule Number* | *Rule* |
|---|---|
| (1) | STORY → SETTING + THEME + PLOT + RESOLUTION |
| (2) | SETTING → CHARACTERS + LOCATION + TIME |
| (3) | THEME → (EVENT)* + GOAL |
| (4) | PLOT → EPISODE* |
| (5) | EPISODE → SUBGOAL + ATTEMPT* + OUTCOME |
| (6) | $\text{ATTEMPT} \rightarrow \left\{\begin{array}{l}\text{EVENT}^{*}\\ \text{EPISODE}\end{array}\right.$ |
| (7) | $\text{OUTCOME} \rightarrow \left\{\begin{array}{l}\text{EVENT}^{*}\\ \text{STATE}\end{array}\right.$ |
| (8) | $\text{RESOLUTION} \rightarrow \left\{\begin{array}{l}\text{EVENT}\\ \text{STATE}\end{array}\right.$ |
| (9) | $\left.\begin{array}{r}\text{SUBGOAL}\\ \text{GOAL}\end{array}\right\} \rightarrow \text{DESIRED STATE}$ |
| (10) | $\left.\begin{array}{r}\text{CHARACTERS}\\ \text{LOCATION}\\ \text{TIME}\end{array}\right\} \rightarrow \text{STATE}$ |

**Source:** Thorndyke (1977, p. 79).

Mandler and Johnson (1977) found that stories conforming to the structure of a story grammar were better recalled than were stories that conformed less well. In fact, people were more likely to "misremember" details that made for a better fit with the story grammar. Interestingly, when these authors analyzed Bartlett's (1932) "War of the Ghosts" story (see Chapter 6), they found that it contained several violations of their story grammar. Some of the recall attempts Bartlett (1932) reported showed errors of recall at precisely these points. We can analyze the problem in a story grammar framework as follows: At least part of the reason why Bartlett's participants had so much trouble remembering the story was that it did not fit the structure they were expecting. They tried to make the story fit the expected structure a little more and, in the process, inadvertently distorted their representation of the story.

Thorndyke (1977) has argued that people use story grammars to guide their reading and their interpretation. One way he tested this idea was to ask people to read and recall various stories he had previously analyzed according to a story grammar. Box 10-5 depicts an example of one of his stories. Thorndyke predicted that the higher up in the levels of the story hierarchy (i.e., the higher the level depicted in Box 10-5) a part of the story occurred, the better it would be recalled, and results confirmed this prediction. Notice that this result is similar to those reported in studies by Kintsch and Keenan (1973), discussed earlier, on which parts of sentences people typically remember.

## Gricean Maxims of Conversation

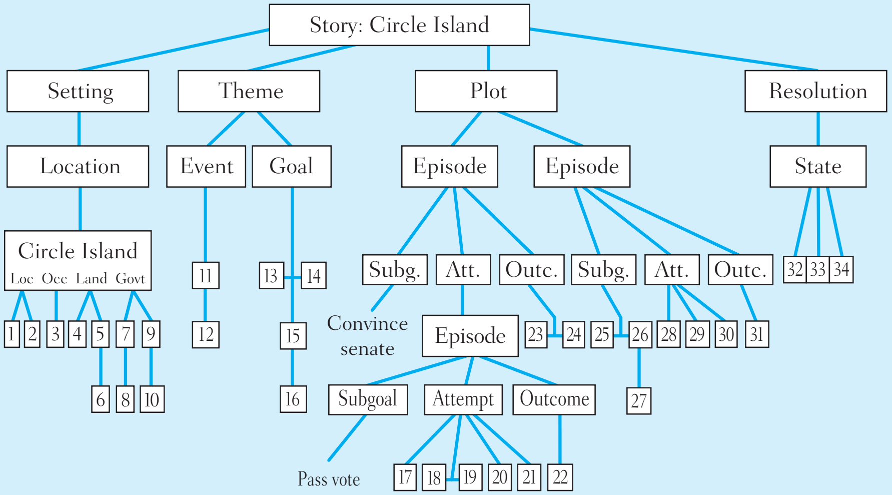
Not all the connected text people must process occurs in written form. We can think of ordinary conversations as examples of spoken connected text. Conversations are interesting to study because they occur so frequently and because (unlike written texts) they normally involve the production of a great deal of language with little time for planning and revision. Indeed, Clark and Van Der Wege (2002) argue,

> the essence of language use is found in face-to-face talk. It is here that speaking and listening arise in their natural, universal states. It is here that researchers can study why speakers say the things they say and how listeners interpret these things—ultimately, as a way of coordinating joint activities. . . .
>
> The problem is that too little is known about spontaneous language and how it differs from reciting, reading aloud, listening to idealized speech, and other such forms. Understanding language in its natural habitat is a major challenge for the second century of psycholinguistics. (p. 250)

We've already seen a number of examples of linguistic rules that people follow in producing or comprehending language. Some of these have to do with ways of combining sounds to produce words, combining words to produce sentences, or

## Box 10-5 Example Story and Its Structure

(1) Circle Island is located in the middle of the Atlantic Ocean, (2) north of Ronald Island. (3) The main occupations on the island are farming and ranching. (4) Circle Island has good soil, (5) but few rivers and (6) hence a shortage of water. (7) The island is run democratically. (8) All issues are decided by a majority vote of the islanders. (9) The governing body is a senate, (10) whose job is to carry out the will of the majority. (11) Recently, an island scientist discovered a cheap method (12) of converting salt water into fresh water. (13) As a result, the island farmers wanted (14) to build a canal across the island, (15) so that they could use water from the canal (16) to cultivate the island's central region. (17) Therefore, the farmers formed a procanal association (18) and persuaded a few senators (19) to join. (20) The procanal association brought the construction idea to a vote. (21) All the islanders voted. (22) The majority voted in favor of construction. (23) The senate, however, decided that (24) the farmers' proposed canal was ecologically unsound. (25) The senators agreed (26) to build a smaller canal (27) that was 2 feet wide and 1 foot deep. (28) After starting construction on the smaller canal, (29) the islanders discovered that (30) no water would flow into it. (31) Thus the project was abandoned. (32) The farmers were angry (33) because of the failure of the canal project. (34) Civil war appeared inevitable.


Story: Circle Island
Setting
Theme
Plot
Resolution
Location
Event
Goal
Episode
Episode
State
Circle Island
Loc Occ Land Govt
1 2 3 4 5 7 9
6 8 10
11
12
13 14
15
16
Subg.
Att.
Outc.
Convince senate
Episode
Subgoal
Attempt
Outcome
Pass vote
17 18 19 20 21 22
Subg.
Att.
Outc.
23 24 25 26 28 29 30 31
27
32 33 34

**SOURCE:** Thorndyke (1977, pp. 80–82).

even combining ideas to produce meanings. Many researchers believe, however, that yet another set of rules is necessary for people to use language appropriately or effectively, especially in conversations: pragmatic rules.

Here we will examine some pragmatic rules specific to conversations called the **Gricean maxims of cooperative conversation** (Grice, 1975). Grice believed that for people to converse, they must do more than produce utterances that are phonologically, syntactically, and semantically appropriate. Consider the following "conversation."

SPEAKER A: I just heard that Joe got promoted today. Isn't that great?
SPEAKER B: Salt Lake City is located in Utah.
SPEAKER C: No, Charles Darwin is the father of modern evolutionary theory.
SPEAKER A: What's the square root of 34?
SPEAKER B: Chocolate ice cream is sweet.

What is wrong with this conversation? Notice that all the sentences are "legal" and at several levels. Each obeys the phonological rules of English. Each is syntactically well formed. Each is meaningful. Yet all together, they don't add up to a conversation. In part, what is going on is a lack of connection between anything one speaker says and anything else another speaker says. Normally in conversation, each of a person's contributions or utterances bears some relation to what others have already said or to what the speaker plans to say later. In this sense, speakers can be said to provide a context for one another's contributions.

Grice (1975) argued that for a conversation to take place, all the speakers must cooperate with one another. Although speakers in a conversation have many choices to make concerning what they will say, as well as when and how they will say it, they must still obey constraints, or general rules (Miller & Glucksberg, 1988). Grice described speakers in a conversation as all following a general "cooperative principle." Speakers do this, Grice believed, by following four specific conversational *maxims* or rules (Grice, 1975):

1. *Maxim of quantity.* Make your contribution as informative as required. Do not make your contribution more informative than is required.
2. *Maxim of quality.* Try to make your contribution one that is true. Do not say what you believe to be false. Do not say that for which you have no evidence.
3. *Maxim of relation.* Be relevant.
4. *Maxim of manner.* Be clear. Avoid obscurity of expression. Avoid ambiguity. Be brief. Be orderly.

Violations of the maxims produce conversations that are noticeably odd. For instance, if someone asks, "Do you have a watch?" and you respond, "Yes, I do," you are violating the first maxim of quantity: You are being less informative than is required. Your conversation partner is not, in all likelihood, taking a census for Timex or Rolex; he or she probably wants to know the time. As a member of

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*Grice proposed four maxims, or rules, that people must follow to have a successful conversation.*

the language community that you live in, you are expected to know that the question asked is really a request for the time and to respond appropriately.

It is also possible to violate the first maxim by being *too* informative. For example, some of my students occasionally invite me to eat with them in the campus dining halls. When we arrange a luncheon date, they often ask something like "Where should we meet?" My response ought to be something on the order of "How about if you come to my office?" rather than something much more detailed like "Please come to my office door, and I will be standing 27 centimeters inside of it." The latter is bizarre, presumably because it's too specific.

The second maxim has to do with truthfulness. Generally, conversation partners assume that the other is telling the truth, or at least what the speaker believes to be the truth. On some occasions, it is permissible to violate this maxim—for example, to be ironic. Imagine that a friend who's missed a lecture in a class in which you are both enrolled asks, "How was class today?" You can respond, "Utterly fascinating!" even if it really was dry as toast, *if* you somehow signal your answer isn't to be taken literally. Rolled eyes, exaggerated intonation, winks, and the like help to communicate that your violation of the maxim of quality is itself meant to communicate something—in this case, ironic humor. If you simply utter an untruthful response without letting your listener know you aren't being candid, then your conversation will not be successful, and your conversation partner could legitimately complain about your conversation skills.

Someone who consistently violates the maxims of quantity or quality may well be perceived as uncooperative or obnoxious and, after a while, may find it difficult to attract conversation partners. Someone who consistently violates the third maxim of relation by responding with irrelevant utterances will have a bigger problem: He or she will simply be regarded as, at best, very bizarre. To illustrate, imagine a conversation between Tom and Joe, two college roommates.

> TOM (*looking around*): Hey, Joe, have you seen my sweater?
>
> JOE (*looking at Tom, and smiling*): Lo, a flaming squirrel!

If Joe persists in violating the maxim of relation, he will likely find himself at a complete loss for conversation partners, if not roommates and friends.

The fourth maxim, the maxim of manner, generally governs the way you choose to construct your conversation contributions. The general idea is that you should speak as clearly as possible, using language appropriate to your listener and the context. Among other things, this maxim forbids you to answer your professors in pig Latin or your younger siblings in "academese." It also prevents you from holding a filibuster (unless you are a member of Congress) and requires that you at least *attempt* to organize what you say before you begin speaking.

Gricean maxims are not always obeyed, but the assumption is that people try to obey them most of the time. When the maxims are violated, the speaker apparently wishes to end the conversation, wishes to avoid the conversation, or expects the listener to understand that the violation is occurring and why (Levinson, 2000; Miller & Glucksberg, 1988). Again, though, it is doubtful that the average person is consciously aware of the rules. As with most linguistic rules, maxims are implicitly understood even if they can't be precisely stated.

## ■ LANGUAGE AND COGNITION

Language is used in ways other than social conversation. Lecturers use language to get ideas across to students, authors to readers, newscasters to audiences, and so on. It should be evident by now that language is used in a number of cognitive processes. When we perceive a familiar object and name it (either aloud or to ourselves), we use language; when we follow one conversation rather than another, we are processing language; when we repeat information aloud or take notes to organize it, we are using language. Similarly, when we reason, make plans, or brainstorm new ideas, we rely heavily on language, as we will see in the next several chapters.

Our use of language in a wide variety of cognitive tasks raises the following important question: What influences does language have over other cognitive processes? Two extreme positions exist: (a) Language and other cognitive processes operate completely independently, and (b) language and other cognitive processes are completely related, with one determining the other. Between the extremes is a broad middle ground, where language and other cognitive processes are seen as related in some ways but independent in others.

The relationship between language and thought has been heavily debated. In the early days of American psychology, John B. Watson (1930) asserted that thought was language and nothing more. In particular, he rejected the idea that thought (internal mental representation or other cognitive activity) could occur without some sort of conditioned language responses occurring. Watson believed that all apparent instances of thinking (such as mentally computing sums, daydreaming about a vacation, weighing the pros and cons of a plan) were really the results of subvocal speech. Thinking was equated with talking to yourself, even if so quietly and covertly that no one (including you) knew you were using language.

Smith, Brown, Toman, and Goodman (1947) conducted a heroic experiment to test Watson's theory. Smith served as the subject and allowed himself to be injected with a curare derivative, which paralyzed all his muscles, necessitating the use of an artificial respirator for the duration of the experiment. Because he could not move any muscles, he could not engage in subvocal speech. The question was, Would this also prevent him from other kinds of cognitive activity? The answer was a decisive *no.* Smith reported remembering and thinking about events that took place while under curare. Apparently, then, subvocal speech and thought are not equivalent.

## The Modularity Hypothesis

A proposal from the philosopher Jerry Fodor (1983, 1985) made a quite different argument about the relationship of language to other aspects of cognition. Fodor argued that some cognitive processes—in particular, perception and language—are *modular.* What does it mean for a process to be a module? First, it means the process is *domain-specific:* It operates specifically with certain kinds of input and not others. With regard to language, for example, Fodor argued that sentence parsing involves processes that are specific to the division of phrases and words into constituents. Such processes are meant only for parsing and are of little use in other cognitive tasks.

Modularity of a process also implies that it is an **informationally encapsulated process:** It operates independently of the beliefs and the other information available to the processor. Another way of explaining this is to say that an informationally encapsulated process operates relatively independently of other processes. Fodor (1983) compared informationally encapsulated processes to reflexes:

> Suppose that you and I have known each other for many a long year . . . and you have come fully to appreciate the excellence of my character. In particular, you have come to know perfectly well that under no conceivable circumstances would I stick my finger in your eye. Suppose that this belief of yours is both explicit and deeply felt. You would, in fact, go to the wall for it. Still, if I jab my finger near enough to your eyes, and fast enough, you'll blink. . . .
>
> [The blink reflex] has no access to what you know about my character or, for that matter, to any other of your beliefs, utilities, and expectations. For this reason the blink reflex is often produced when sober reflection would show it to be uncalled for. (p. 71)

The **modularity hypothesis,** then, argues that certain perceptual and language processes are modules. (In the case of language, one such process is that which parses input utterances.) These processes are thought to be set apart from other cognitive processes, such as memory, attention, thinking, and problem solving, that are thought to be nonmodular. Modular processes operate automatically and independently (at least at the first stages of processing) of other cognitive processes, such as thought. Modular processes are domain specific, which means that they are specialized to work with only certain kinds of input. The syntactic parsing aspects of language are not used in other kinds of cognitive processing. In this sense, then, language really is a special and very independent cognitive process.

Is there evidence for the modularity hypothesis? The experiment by Swinney (1979) on lexical ambiguity resolution offers findings that support the modularity hypothesis. Recall that Swinney found that when people are presented with an ambiguous word (even in a context that should disambiguate the meaning of the word), all possible meanings are triggered for a fraction of a second. This triggering appears to be automatic and reflexive, and completely independent of whatever other cognitive processes might be operating at the time. That all the meanings are activated, independent of the context, demonstrates some informational encapsulation.

## The Whorfian Hypothesis

The modularity hypothesis can be taken as a proposal for treating language (or at least certain aspects of language) as quite independent of any other cognitive process. Other investigators have argued for a different proposal: Strong relations exist between language and other cognitive processes. One hypothesis, called the **Whorfian hypothesis of linguistic relativity,** was originated by Benjamin Whorf, a chemical engineer whose hobby was studying Native

American languages of North America. It states that language both directs and constrains thought and perception. Whorf (1956) stated the hypothesis as follows:

> We dissect nature along lines laid down by our native languages. The categories and types that we isolate from the world of phenomena we do not find there because they stare every observer in the face; on the contrary, the world is presented in a kaleidoscopic flux of impressions which has to be organized by our minds—and this means largely by the linguistic systems in our minds. We cut nature up, organize it into concepts, and ascribe significance as we do, largely because we are parties to an agreement to organize it in this way—an agreement that holds through our speech community and is codified in the patterns of our language. The agreement is, of course, an unstated one, but its terms are absolutely obligatory. (pp. 213–214)

Whorf believed that the language or languages one grows up learning and speaking thus determine the way one perceives the world, organizes information about the world, and thinks. Whorf (1956) based his hypothesis on the observation that each language differs in how it emphasizes various aspects of the world. For example, he observed that the Eskimo language has several words for snow, whereas English has one. (In a very amusing essay, Pullum, 1991, offered evidence and arguments to refute this belief about Eskimos and snow.) English has a number of words to describe basic colors, but the language of the Dani, an Indonesian agricultural group, has only two: *mili* for dark or black and *mola* for white or light (Heider, 1972). Whorf's hypothesis predicts that these language differences could limit the information available to speakers of different languages: As English speakers, we might fail to make distinctions between kinds of snow that Eskimos are thought to make routinely. Similarly, the Dani might process information about colors in very different ways from us because of differences in language about color terms.

Eleanor Rosch (formerly Heider) conducted a series of studies that directly tested the Whorfian hypothesis. If Whorf is correct, then the Dani should have great difficulty perceiving or remembering colors not named in their language (such as green versus yellow), relative to speakers of English, whose language names each color. Dani-speaking and English-speaking participants were shown various color chips. Some depicted basic or *focal* colors—chips considered to be the best examples of basic color terms (say, a very green green, as opposed to a blue green). Others depicted nonfocal colors, those that English speakers would describe as a combination of focal colors or as a shade of a focal color (such as light pink, scarlet, olive green, aquamarine).

Heider (1972) presented participants with a chip of either a focal or a nonfocal color, typically for 5 seconds. Thirty seconds later, they were shown 160 color chips and asked to point to which one matched the chip they had just seen. Like English speakers, and contrary to Whorf's hypothesis, Dani speakers performed much better if the initial chip showed a focal rather than a nonfocal color. In another experiment, Rosch (1973) asked participants to learn new, arbitrary names for colors. Once again, Rosch found that Dani speakers, like English speakers, performed better when the colors shown were focal rather than nonfocal.

Apparently, then, even if a language does not mark particular differences, it does not always prevent its speakers from either perceiving those differences or learning them, contrary to Whorf's hypothesis. Indeed, work by anthropologists Berlin and Kay (1969) suggests that all languages observe certain rules about the way colors are named. They found that in every language, no more than 11 basic color terms (that is, not derived from other color terms) are recognized.

Moreover, the way colors are recognized is hierarchical. The hierarchy is depicted in Table 10-3. It shows that if a language has only two color terms, they are always something corresponding to "black" (or "dark") and "white" (or "light"). If a language has three color terms, then a term meaning "red" is added to this list. Languages with four color terms also have either a term for "green" or one for "yellow," but not both, and so on. English, which recognizes all 11 terms as names for focal colors, includes words for all the colors in the hierarchy. No other language recognizes more colors as basic. The implication here is that color terms and concepts are in an important way universal. However,

**Table 10-3** Hierarchy of Color Terms in Different Languages

| *Number of Color Terms* | *Names of Color Terms* |
|---|---|
| 2 | white, black |
| 3 | white, black, red |
| 4 | white, black, red, and either yellow or green |
| 5 | white, black, red, yellow, green |
| 6 | white, black, red, yellow, green, blue |
| 7 | white, black, red, yellow, green, blue, brown |
| 8 through 11 | white, black, red, yellow, green, blue, brown plus some combination of one or more of the following: pink, purple, orange, gray |

**Source:** After Berlin and Kay (1969).

some have argued that because Rosch's task depended so heavily on color perception (which may have physiological determinants), it is not as crucial a test of Whorf's hypothesis as it was claimed to be (Hunt & Agnoli, 1991).

A more recent controversy regarding linguistic relativity comes from a proposal of Alfred Bloom (1981), who proposed to study a weaker form of the Whorfian hypothesis: The presence of certain linguistic markers makes some kinds of comprehension and thinking easier or more natural. Specifically, Bloom noticed that the Chinese language lacks a structure equivalent to those in Indo-European languages that marks a *counterfactual inference,* such as "If your grandmother had been elected president, there would be no taxation." Counterfactuals require inferences to be drawn on the basis of a premise known to be false. By using the past tense of the verb, or by the phrase "were to" in the first clause, English marks the fact that the premise is false. In contrast, Chinese has no direct marker of a counterfactual, although there are various indirect ways of getting the idea across.

On the basis of anecdotal evidence from Chinese-speaking associates, Bloom (1981) hypothesized that Chinese speakers would have a more difficult time drawing counterfactual inferences than would speakers of English, especially when text passages containing counterfactual inferences were difficult. In a series of studies, Bloom gave both Chinese-speaking and English-speaking participants different stories to read in their native languages. He reported that only 7% of the Chinese-speaking participants offered counterfactual interpretations of the story, whereas 98% of the English-speaking participants did so. At first blush, these findings offered nearly perfect confirmation of Bloom's predictions (which, recall, were predictions derived from the Whorf hypothesis).

Later investigations by native Chinese speakers, however, disputed Bloom's findings. They maintained that various *artifacts,* or unrelated aspects of the way he conducted the studies, accounted for his results. Au (1983, 1984), for instance, argued that Bloom's Chinese versions of his story were unidiomatic—that is, awkwardly phrased. When she provided new and more idiomatic stories to her Chinese-speaking participants, they showed very little difficulty responding idiomatically. Liu (1985) replicated Au's findings on counterfactual interpretations with Chinese-speaking participants who had minimal or no exposure to the English language. Recently, a spirited debate has emerged between Li and Gleitman (2002) and Levinson, Kita, Huan, and Rasch (2002) over whether speakers of different languages encode spatial directions differently, constructing fundamentally different structures of space.

Apparently, then, little evidence suggests that language constrains either perception (as demonstrated in the color naming studies) or higher-level forms of thinking (as demonstrated in the counterfactual reasoning studies). This is not to say that language has no effects on people's thinking, only that empirical evidence causes us to reject the original, strong form of Whorf's hypothesis. Bates, Devescovi, and Wulfeck (2001) summarize the ideas as follows:

> We are not suggesting that some languages are inherently harder to learn, process, or retain under brain damage than others. All languages must have achieved a roughly comparable degree of learnability and processability across the course of history, or they would not still be around. However, overall processability is the product of cost–benefit tradeoffs, a constraint satisfaction problem that must be solved across multiple dimensions of the language system. As a result, we may obtain powerful differences between languages in the relative difficulty of specific language structures, with differential effects on performance be children, aphasic patients, and healthy normal adults. (p. 374)

Nonetheless, it is true that language at least reflects thought in many instances. For example, although most of us have only a single word for snow, those interested in the white stuff (such as skiers) have developed a more extensive vocabulary, presumably to communicate better about conditions on the slope. In general, experts or connoisseurs in given areas do tend to develop their own specialized vocabularies that reflect distinctions and differences that novices might have difficulty (at first) seeing or labeling. Presumably, this is because the experts need to communicate about the subtle differences and so develop the enabling vocabulary. Novices, who have little need to discuss the differences, don't develop the vocabulary (nor, by the way, do they develop the perceptual differentiation skills, as we saw in Chapter 3).

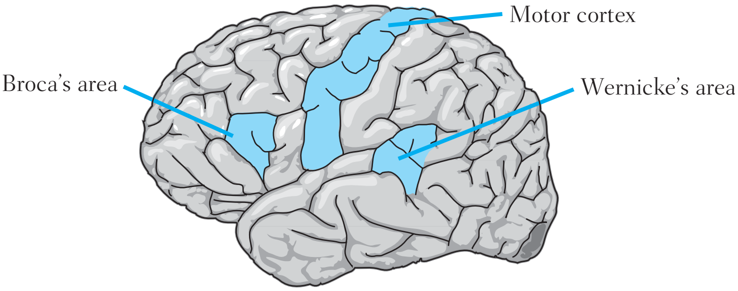
## Neuropsychological Views and Evidence

That we process complex language information with amazing speed is an understatement. Caplan (1994) reported, for example, that people typically recognize spoken words after about 125 milliseconds (about one eighth of a second!)—that is, while the word is still being spoken. Normal word production, estimated over a number of studies, requires us to search through a mental "dictionary" of about 20,000 items, and we do so at the rate of three words per second.

Obviously, the brain architecture to support this rapid and complex cognitive processing must be sophisticated indeed. Neuropsychologists have been trying to understand what the underlying brain structures involved with language are, where they are located, and how they operate. In this section, we will take a brief look at some of the major findings.

Interest in *localizing* language function in the brain dates back at least to the 1800s, when a French physician with interests in anthropology and ethnography, Pierre Paul Broca, read a paper in 1861 at the meeting of the Société d'Anthropologie in Paris. The paper reported on a patient, nicknamed "Tan" because he had lost the ability to speak any words save for *tan.* Shortly after the patient died, his brain was examined and found to have a lesion in the left frontal lobe. The very next day, Broca reported this exciting (for science, not for the patient or his family, probably) finding (Posner & Raichle, 1994). The area of the brain, henceforth known as *Broca's area*, is shown in Figure 10-8. Subsequently, several other patients were reported who had similar difficulties in speaking and who were found to have lesions in the same brain region.

**FIGURE 10-8** ■ *Some underlying brain structures involved with language.*



About 13 years later, a German neurologist Carl Wernicke identified another brain area that, if damaged by a small lesion (often the result of a stroke), left patients with extreme difficulty *comprehending* (but not producing) spoken language (Posner & Raichle, 1994). (Not surprisingly, this area has come to be called *Wernicke's area,* and it is also shown in Figure 10-8.)

Both these language disorders were termed **aphasia,** although the first was called **expressive aphasia** (or **Broca's aphasia**) and the second **receptive aphasia** (or **Wernicke's aphasia**). Broca's aphasia appeared to leave language reception and processing undisturbed; Wernicke's, to spare fluent production of words and sentences (although the language was often gibberish). More recent evidence provides qualifications to these statements, suggesting, for example, that patients with Broca's aphasia do have some difficulties in understanding spoken language. Thus our understanding of different kinds of aphasia is becoming more elaborated. Other kinds of aphasia have also been reported and correlated with brain damage in specific brain regions, often ones adjacent to Broca's or Wernicke's areas (Banich, 1997).

Researchers studying aphasia also noticed an interesting generalization about aphasic patients: Usually the area of damage to the brain was in the left and not the right hemisphere. This led to the idea that the two cerebral hemispheres of the brain play different roles and have different functions. The term for this specialization of function between the two hemispheres is **lateralization.**

Briefly, it appears that in most people the left cerebral hemisphere is associated with the ability to produce and comprehend language and the right hemisphere, with the ability to process complex spatial relationships (Springer & Deutsch, 1998). Evidence for this lateralization began with the clinical observation (beginning with Broca) of aphasic patients. Other evidence comes from a test used with people about to undergo brain surgery for epilepsy, called the *Wada test*. This involves injecting a barbiturate drug, sodium amobarbital, into one of two carotid arteries: either the one going to the left hemisphere or the one going to the right hemisphere. The injection anesthetizes one of the hemispheres. The patient is kept conscious during this procedure and, just before the injection, is asked to hold up his or her two arms and to start counting. When the drug reaches the intended hemisphere, the patient drops the arm that is on the opposite side of the body from the side anesthetized. The human brain, like those of other animals, is organized in such a way that the right hemisphere controls the left side of the body and vice versa, so the dropping of the arm signals the physician that the drug has arrived at the brain. If the anesthetized hemisphere is the one controlling language abilities, the patient will, soon after his or her arm drops, experience a 2- to 5-minute period during which he or she is unable to speak (Springer & Deutsch, 1998).

Not all people have language in the left hemisphere. About 96% of right-handers do, with the other 4% showing a mirror-image pattern: language in the right hemisphere. Left-handers show a different pattern: Seventy percent of them still show language in the left hemisphere, 15% show language in the right hemisphere, and the remaining 15% show language in both hemispheres (Banich, 1997).

Technologies such as CAT and PET scans have also been used to study language functioning in both aphasic and nonaphasic people. Kempler et al. (1990) studied three patients with an aphasia known as *slowly progressive aphasia,* noting either normal or mild atrophy of the left language regions (shown by CAT scans) and hypometabolism (that is, less use of glucose) by the left hemispheres of the three patients.

A now classic study conducted by Petersen, Fox, Posner, Mintun, and Raichle (1988) examined the processing of single words using PET scans. Participants were presented with single words, either in writing or auditorily, and were asked either to make no response, to read written stimuli, or to generate a word related to the presented word. Results showed that different areas of the brain were activated for different tasks. Simply viewing visually presented words led to activation of the inner left hemisphere, in the occipital lobes (the part of the brain known to be specialized for visual information). When the task was simply to listen to words, participants showed elevated cortical activity in the temporal lobes (known to be the area of the brain having to do with auditory processing, which includes Wernicke's area) of both hemispheres.

One important finding from the study is that the areas activated did *not* overlap. In other words, the area of the brain activated in written-word recognition is separate from that area activated when words are heard. When presented with a visual word and asked to pronounce it, participants showed activation in both hemispheres, but this time in the motor cortex, the part of the brain that directs motor behaviors. Interestingly, the PET scans did not show elevated levels of activity in either Wernicke's or Broca's areas (Posner & Raichle, 1994). However, when participants were asked to generate another word in response to the one presented, many areas of the brain previously quiet became active, including Broca's area. Many of the findings reported by Petersen et al. (1988) have been replicated using functional magnetic resonance imaging (fMRI), a newer noninvasive technique (Cuenod et al., 1995).

Other research, however, has clouded this neat picture. Not all patients with lesions in Broca's area, for example, develop Broca's aphasia, and not all patients with Broca's aphasia have damage in Broca's area. Moreover, not all Broca's aphasia patients show the same degree of impairment; many of them show an inability to process subtle nuances of language. The story is similarly complicated with Wernicke's aphasia.

Caplan (1994) concluded that the localization of specific language processing in particular brain regions is not straightforward. One possible idea entertained by Caplan is that language processes do not necessarily have a specific location in the brain. Instead, they may be distributed across a region of the brain in a neural network configuration similar to the connectionist models presented in Chapters 1 and 7 (see Christiansen and Chater, 2001, for a description of some such models). The exact location differs from individual to individual, but probably lies somewhere on a pathway connecting the frontal, parietal, and temporal lobes (Catani, Jones, & Ffytche, 2005). Small lesions in any one area are unlikely to "knock out" an entire language process, but larger lesions might.

Obviously, much work is needed with the newer neuroimaging techniques to test many of these intriguing ideas (Gernsbacher & Kaschak, 2004). However, at present it looks as if Fodor's modularity idea is gaining some support from the neurolinguistic and neuropsychological data reported to date. How well this proposal will withstand further tests is an open question.

## SUMMARY

1. To be a language, a system must exhibit regularity (that is, be governed by a system of rules, called a *grammar*) and productivity (be able to express an infinite number of ideas).

2. When researchers say that people "follow" the rules of a language, they distinguish between conscious awareness of a rule (which neither psychologists nor linguists believe is the way people apply most linguistic rules) and implicit access to a rule (such that a person follows a rule, though perhaps unaware of its existence and unable to articulate just what the rule is).
3. Language is structured on several levels: the phonological (sound), syntactic (ordering and structuring of words and phrases in sentences), semantic (meaning), and pragmatic (the ways in which language is actually used), to name a few. Each of these levels has a different set of rules associated with it.
4. People use different linguistic rules both when they produce and when they comprehend language. The ways in which a number of our perceptual systems are set up help people master the very complicated task of processing language relatively easily. Despite ambiguity in many of the utterances we encounter, we can use the context of the utterance as well as other strategies to settle on the most likely intended meaning.
5. Perceptual context effects exist at many levels. Context can affect even the perception of individual sounds. The phoneme restoration effect demonstrates that people effortlessly "fill in" experimentally created gaps in a stream of speech. Context affects the ways in which individual words are interpreted, although Swinney's (1979) study suggests that context effects operate not instantaneously but after a brief (fraction of a second) period.
6. People seem to parse sentences into syntactic constituents as they construct the sentence's meaning. They appear to discard the exact wording of a sentence and to retain only its gist when they finish the processing. Many sentences involve some sort of ambiguity, which people seem to resolve very quickly.
7. In processing text passages, listeners and readers seem to be affected by the difficulty of the individual words and the syntactic complexity, as well as by the propositional complexity, the relationships among sentences, and the context in which the passage is presented. Some cognitive psychologists believe that people use story grammars to comprehend large, integrated pieces of text.
8. Conversations, spoken versions of texts, also seem governed by a system of implicit rules known as the *Gricean maxims of cooperative conversation.* Speakers who consistently violate the maxims are doing so for humorous or ironic effect, trying to end or avoid a conversation, being inattentive or inappropriate, or showing a gross disregard for the expectations of their conversation partners.
9. Two distinct proposals regarding the relation of language to other cognitive processes are the modularity hypothesis and the Whorfian hypothesis of linguistic relativity. The modularity hypothesis proposes that some aspects of language, especially syntactic processes, function autonomously, independent of any other cognitive process. This proposal, being relatively recent, awaits

rigorous empirical testing, although some evidence is consistent with it. The strong version of the Whorfian hypothesis of linguistic relativity, despite its intriguing nature, has so far failed to receive strong or lasting empirical support.

10. The development of various neuroimaging techniques has allowed researchers to construct detailed “brain maps” that localize different functions. There is some ongoing disagreement over just how localized any one language process is.

## REVIEW QUESTIONS

1. Describe and evaluate the criteria that linguists and psychologists use to distinguish between (human) languages and communication systems.
2. What does the term *grammar* mean to linguists and psychologists? How does their understanding of the term differ from that of a layperson?
3. Explain the competence/performance distinction and the arguments linguists and psychologists give for making it.
4. What does it mean to say that our knowledge of linguistic rules is implicit rather than explicit? Discuss the implications of this statement.
5. Contrast the Gricean maxims of conversation with syntactic and phonological rules.
6. Describe the modularity hypothesis and its implications for the study of language as part of cognitive psychology.
7. What is the Whorfian hypothesis of linguistic relativity? Evaluate the empirical evidence bearing on it.
8. In what ways do (and don’t) neuropsychological findings support Fodor’s modularity hypothesis?

## KEY TERMS

aphasia
Broca’s aphasia
expressive aphasia
grammar
Gricean maxims of cooperative conversation
informationally encapsulated process
lateralization
lexical ambiguity
linguistic competence
linguistic performance
modularity hypothesis
morpheme
phoneme
phonetics
phonology
pragmatics
propositional complexity
receptive aphasia
semantics
story grammar
syntax
Wernicke’s aphasia
Whorfian hypothesis of linguistic relativity

## CogLab DEMONSTRATIONS

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

CogLab provides two relevant demonstrations, both illustrating the phenomenon of categorical perception of speech. These are **Categorical Perception-Identification**, and **Categorical Perception-Discrimination**. Both are worth trying!

## WEB RESOURCES

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

## CHAPTER

## 11

# Thinking and Problem Solving

**Classic Problems and General Methods of Solution**
- Generate-and-Test Technique
- Means–Ends Analysis
- Working Backward
- Backtracking
- Reasoning by Analogy

**Blocks to Problem Solving**
- Mental Set
- Using Incomplete or Incorrect Representations
- Lack of Problem-Specific Knowledge or Expertise

**The Problem Space Hypothesis**

**Expert Systems**

**Finding Creative Solutions**
- Unconscious Processing and Incubation
- Everyday Mechanisms

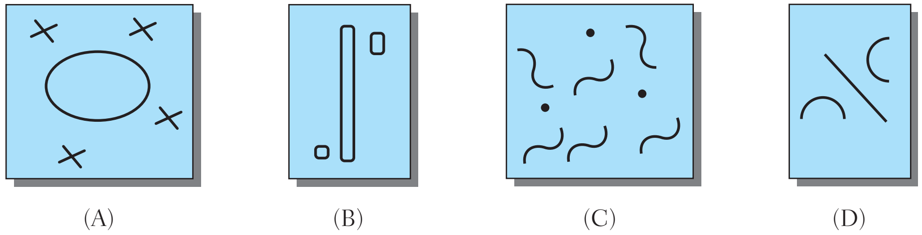
**Critical Thinking**

This chapter is about different kinds of thinking and **problem solving,** the kind of mental work you do in each of the following tasks:

1. Think of your favorite restaurant. What is its name? Where is it? What are its best dishes? What makes it your favorite?
2. Solve this problem: If 10 apples cost \$2, how much do 3 apples cost?
3. Create unusual but appropriate titles for the drawings shown in Figure 11-1; for example, "Giant egg on a baseball diamond" for Figure 11-1(A).
4. Consider whether a change in one of your school's policies (for example, dropping all distribution requirements) would have overall beneficial or harmful effects.

In this chapter, we will examine descriptions and explanations for the mental work you have just done. How did you accomplish the tasks? What processes did you use? We will look at a number of different thinking tasks and discuss what makes thinking either easy or hard.

**FIGURE 11-1** ■ *Ambiguous drawings.*



(A) (B) (C) (D)

*Thinking* is a broad term. Psychologists who study thinking often study what look like very different tasks. Defining *thinking* turns out to be a tough job, and one that itself requires thought. **Thinking** has been defined as "going beyond the information given" (Bruner, 1957); as "a complex and high-level skill" that "fill[s] up gaps in the evidence" (Bartlett, 1958, p. 20); as a process of searching through a problem space (Newell & Simon, 1972); and as what we do "when we are in doubt about how to act, what to believe, or what to desire" (Baron, 1994, p. 3).

Clearly, the term *thinking* is used to refer to more than one specific activity. This suggests there may be different types of thinking. One distinction that may prove useful is between *focused* and *unfocused* thinking. Focused thinking begins with a clear starting point and has a specific goal. (We will see examples of focused thinking in this chapter, as well as in much of the material in Chapters 12 and 13.) Unfocused thinking has the character of daydreaming, or unintentionally calling to mind a number of different and loosely related ideas. We will primarily explore focused thinking, especially in the first section of the chapter, in the discussion on problem solving. We will then turn to creative thinking, which some have described as including aspects of unfocused thinking. Finally, we will examine how people evaluate the products of their thinking. In particular, we will look at the ways in which people assess their ideas, reflect on the implications of their conclusions, and guard against bias or impulsivity.

You may wonder why psychologists study thinking through the use of problems and puzzles that appear *not* to mirror the kind of thinking that occurs in everyday life (such as when you think about what shirt to wear, what to order in a restaurant, or what route to take to get to work). One reason stems from the intuition that everyday thinking often occurs so rapidly and automatically that it would be hard to study. Moreover, people likely bring much of their background knowledge to bear in their everyday thinking. You presumably choose what to wear for the day on the basis of what you expect to be doing and perhaps on external standards or expectations regarding dress. Because people have varying background knowledge and goals, then, it would be nearly impossible to devise a problem that is equal in difficulty for different individuals. By presenting standardized sets of problems, investigators have more control over the information participants have available and how it is given to them. We will see some examples of everyday problem solving in Chapter 16.

Various problems are presented throughout the chapter as opportunities to work with the phenomena of thinking. I suggest that to maximize the value of these undertakings, you rely on a time-honored method of observation in experimental psychology: introspection. **Introspection** is the detailed, concurrent, and nonjudgmental observation of the contents of your consciousness as you work a problem. Although introspection has problems and critics (see Ericsson & Simon, 1984, for a detailed summary), it can at the very least provide the basis for hypotheses and tests using more objective measures. The key to proper use of this technique is to avoid doing more than is asked for: Don't explain or justify what you're thinking about, just report it. Box 11-1 provides instructions on how to introspect. Before you read further, obtain paper and a pen or pencil for note taking or, preferably, a tape recorder into which you can record your thoughts as you work the problems. Work in the privacy of your room or some other quiet place. You won't be showing your notes or tapes to anyone else, so don't censor or try to control your thoughts—just be a careful observer. To assess how well the theories describe your performance, you can then compare your notes with descriptions of the theories presented.

The problems presented are similar in at least one respect: They fall into the class of problems called *well defined.* **Well-defined problems** have a clear goal (you know immediately if you've reached the solution), present a small set of information to start from, and often (but not always) present a set of rules

### Box 11-1 Instructions for Introspecting

1. Say whatever's on your mind. Don't hold back hunches, guesses, wild ideas, images, intentions.
2. Speak as continuously as possible. Say something at least once every 5 seconds, even if only, "I'm drawing a blank."
3. Speak audibly. Watch out for your voice dropping as you become involved.
4. Speak as telegraphically as you please. Don't worry about complete sentences and eloquence.
5. Don't overexplain or justify. Analyze no more than you would normally.
6. Don't elaborate past events. Get into the pattern of saying what you're thinking now, not of thinking for a while and then describing your thoughts.

**SOURCE:** Perkins (1981, p. 33).

or guidelines to abide by while you are working toward a solution. In contrast, **ill-defined problems** don't have their goals, starting information, or steps clearly spelled out.

The difference between well- and ill-defined problems can be illustrated as follows. Consider the problem of figuring the sales tax on a purchase, given that you know the price of the item you are buying, whether it is taxable, the rate of taxation, and basic rules of multiplication. If you are armed with this background information, it should be relatively easy for you, a college student, to arrive at the tax. Contrast this with another problem often encountered: composing a letter that articulately and sensitively conveys a difficult message (for example, a "Dear John" or "Dear Jane" letter to someone you're still fond of, or a letter to your boss asking for a promotion). It's not clear in any of these cases of ill-defined problems what information you should start from (how much of your education and how many of your qualifications and past year's accomplishments do you tell your boss about?). It's not clear when you've reached the goal (is the current draft good enough, or can it be made better?) or what rules (if any) apply.

Image not available due to copyright restrictions

Psychologists have focused on well-defined problems for several reasons: They are easy to present, they don't take weeks or months to solve, they are easy to score, and they are easy to change. It is assumed that problem solving for ill-defined problems works in similar ways to problem solving for well-defined problems, although the assumption has not been extensive tested (Galotti, 1989). In one study, Schraw, Dunkle, and Bendixen (1995) demonstrated that performance on well-defined problems was not correlated with performance on an ill-defined one.

## ■ CLASSIC PROBLEMS AND GENERAL METHODS OF SOLUTION

The way to solve a problem depends, to a great extent, on the problem. For instance, if your problem is to fly to Los Angeles, you might call various airlines or travel agents or even surf the web pages of relevant airlines or general travel websites such as Orbitz or Travelocity. In contrast, if your problem is to balance your checkbook, you normally would not ask for assistance from a travel agent, but you might from a banker. These are *domain-specific* problem-solving approaches—they only work for a limited class of problems. Here, I will only be reviewing a certain class of general, domain-independent techniques. These methods are stated at a general enough level that, in principle, they can be used with a wide variety of problems, not just with problems of a certain type or domain.

### Generate-and-Test Technique

Here is the first problem for you to try. Think of 10 words beginning with the letter *c* that are things to eat or drink. Write down all the things that occur to you, even if they end up not meeting the criteria. How are you solving this problem?

I faced a real-life problem somewhat like this several years ago. I was in Minnesota and had to get 100 Swiss francs to a hotel in Bern, Switzerland, within a week to hold a room reservation. I went to the post office to get an international money order but discovered it would take about a month for the order to make its way to the hotel. I deliberated over how to solve the problem, talking to lots of friends who've traveled more extensively than I, and came up with a number of ideas. I could call people at American Express and see if they could help. I could see if by chance any of my friends would be traveling to Bern in the next week. I could call Western Union and wire the money. I could get a cashier's check from a bank. I could go to my automobile club, purchase a traveler's check in Swiss francs, and mail it. The first four options, as it turned out, wouldn't work or were much too expensive. The fifth one met my criteria of being possible, working within a week's time, and being (relatively) affordable, so that was the one I chose.

The process that I used in solving this problem is a good example of the **generate-and-test technique.** As the name suggests, it consists of generating possible solutions (for example, "Let's call people at American Express and see if they can help") and then testing them (for example, "Hello, American Express? Can you help me with the following problem . . . ?"). The tests didn't work for the first four possibilities but did for the fifth (it would work, the cost was reasonable, and the money would get there in time).

You may have used generate-and-test to solve the problem of listing 10 words that begin with *c* that name things to eat or drink. When I worked on this problem, some names came to mind that sound as if they started with *c* but don't (for example, *ketchup* [unless you spell it *catsup*] and *sarsaparilla*), and some that start with *c* but aren't edible or drinkable (*cable, canoe*). Again, the process used was thinking of possible solutions (generating) and then seeing if those possibilities met all the criteria (testing).

Cheerios
LOW FAT
CHEESE NIPS
AIR CRISPS
DAIRY MILK
PHILADELPHIA Light
COLBY

Nancy J. Ashmore

*How many foods can you think of that begin with c? Here are some examples: cream cheese, candy, cookies, celery, carrots, cantaloupe, cheese, cocoa, cereal (Cheerios), and crackers (Cheese Nips).*

Generate-and-test is a technique that loses its effectiveness very rapidly when there are many possibilities and when there is no particular guidance for the generation process. If you forget the combination to your locker, for instance, the technique will eventually work, but your frustration level by that time might exceed your willingness to persevere with the task. Moreover, if you don't have a way to keep track of the possibilities you have tried, along with the ones you have yet to try, you might be in real trouble. There's a joke in the movie *UHF* in which a blind man working on a Rubik's cube puzzle sits next to a sighted man. The blind man twists the Rubik's cube into a particular pattern, thrusts it in front of the sighted man, and asks, "Is this it [the correct pattern]?" "No," says the latter. The interchange is repeated, rapidly, several times. The joke is that this method of problem solving is all but doomed to failure, given the large number of possible configurations and the lack of any systematic way of trying them.

Generate-and-test can be useful, however, when there aren't a lot of possibilities to keep track of. If you've lost your keys somewhere between the cafeteria and your room and you made intermediate stops in a classroom, the snack bar, and the bookstore, you can use this technique to help you search.

## Means–Ends Analysis

Suppose you want to visit a friend who lives in Summit, New Jersey, and you are currently residing in Pomona, California. There are several possible means of transportation: walking, bicycling, taking a taxi, taking a bus, taking a train, driving my car, or taking a plane or helicopter. The most practical means might be to fly on a commercial airline; it's the fastest and fits your budget. However, to board your flight you have to get to the nearest airport, 5 miles east of your residence. Again, you could walk, bicycle, take a taxi, and so on. The most efficient and cost-effective means is to drive your car. However, the car is parked in the garage, not where you are sitting when you are ready to depart for the airport. So you have to get to the car. You would probably choose to walk there (as opposed to, say, calling a cab).

The technique of problem solving described here is called **means–ends analysis.** It involves comparing the goal (Summit, New Jersey) with the starting point (Pomona, California), thinking of possible ways of overcoming the difference (walking, bicycling, taking a taxi, and so on), and choosing the best one. The selected option (taking a plane) may have certain prerequisite conditions (for example, being at the airport, with a ticket). If the preconditions aren't met, then a *subgoal* is created (for example, "How can you get to the airport?"). Through the creation of subgoals, the task is broken down into manageable steps that allow a full solution to be constructed.

Newell and Simon (1972) and their associates studied means–ends analysis while solving certain arithmetic problems, such as the following:

$$\begin{array}{r} \text{DONALD} \\ +\ \text{GERALD} \\ \hline \text{ROBERT} \end{array}$$

Given that D = 5, determine the values for the other letters. (Problems in which letters stand for digits are known as *crypt arithmetic* problems.)

The researchers created a computer program, called **GPS,** or **General Problem Solver,** which solves problems in crypt arithmetic and in logic using means–ends analysis. GPS uses the following basic strategy. First, it looks at the object it is given (such as the preceding crypt arithmetic problem with letters) and compares it with the desired object (an arithmetic problem with numbers in place of all letters, in which the solution is actually the addition of the two numbers above the line). By doing so, GPS detects any differences between the actual and the desired object.

Next, GPS considers the operations available to change objects. Here, the available operations include those that replace certain letters with certain digits, for example, D = 5. The operations used are chosen with the aim of reducing differences between actual and desired objects. In cases where none of the available operations applies to the actual object, GPS tries to modify the actual object so that operations can apply. GPS also tries to keep track of various kinds of differences between desired and actual objects and to work on the most difficult differences first. Thus if several possible operations are found, all of which could apply to an actual object, GPS has some means of ranking the different operations such that certain ones are used first.

Newell and Simon (1972) gave several problems in logic and in crypt arithmetic to both human participants and GPS and compared the "thinking" of both. Human participants generated verbal protocols, much like the ones you have been asked to generate as you have read this chapter; GPS produced a printout of its goals, its subgoals, and the operations it applied as it worked.

Comparing the protocols generated, Newell and Simon concluded that there were many similarities between the performance of GPS and the performance of the Yale students who served as participants. Notice that means–ends analysis, the general heuristic, or shortcut strategy, used by GPS, is a more focused method of solution than generate-and-test: It guides the problem solver more in choosing what step to take next. Means–ends analysis also forces the problem solver to analyze aspects of the problem before starting to work on it and to generate a plan to solve it. Often this requires establishing subgoals. Notice here that the problem solver is acting less "blindly" and only after some thought.

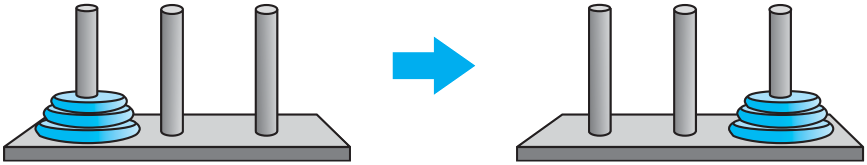
Means–ends analysis is not always the optimal way to reach a solution, however, because sometimes the optimal way involves taking a temporary step backward or further from the goal. For example, imagine you live in an eastern suburb of Los Angeles but want to take a flight from Los Angeles to Denver. To do so, you have to move, temporarily, a greater distance (further west) from your goal than your current distance. Means–ends analysis can make it more difficult to see that the most efficient path toward a goal isn't always the most direct one.

## Working Backward

Another general problem-solving technique is called **working backward.** Its user analyzes the goal to determine the last step needed to achieve it, then the next-to-last step, and so on. In the problem of getting to my mother's house, for instance, the very last step is to walk from outside her front door into the house. The problem in getting to her front door from the Tampa airport can be solved by taking a cab to her house. I can get a cab at the airport, and so on. Working backward often involves establishing subgoals, so it functions similarly to means–ends analysis.

Working backward is a very important technique for solving many problems, including the famous Towers of Hanoi problem, depicted in Figure 11-2. A successful episode of problem solving might be something like the following: "First I have to get the bottom disk moved over. But to do that I have to move the top two disks. I can do that if I move the second disk to the spare peg, but to do that I have to move the top disk out of the way. I could do that by temporarily moving it to the goal peg, then moving the second disk to the spare peg, then moving the top disk back to the spare peg, then moving the bottom disk over." Notice that the solution process usually does not start with the problem solver making a move and seeing what happens. Instead, even after only a little practice, the usual pattern is to plan moves in advance, setting up many intermediate goals along the way (Egan & Greeno, 1974). Of course, it takes a few trials before the problem solver adopts the correct solution; if the puzzle consists of more than three disks, the participants are unlikely to solve it with the minimum number of moves on the first few trials (Xu & Corkin, 2001).

**FIGURE 11-2** ■ *The Towers of Hanoi problem. Determine a sequence of moves to transfer the three disks from the first to the third peg, moving only one disk at a time and never placing a bigger disk on top of a smaller one.*



Working backward is most effective when the backward path is unique, which makes the process more efficient than working forward. And, as you may have noticed, working backward shares with means–ends analysis the technique of reducing differences between the current state and the goal state.

## Backtracking

Try this next problem. Imagine there are five women: Cathy, Debbie, Judy, Linda, and Sonya. Each of the five women owns a different breed of dog (a Bernese mountain dog, a golden retriever, a Labrador retriever, an Irish setter, or a Shetland sheepdog). And each has a different occupation (clerk, executive, lawyer, surgeon, or teacher). Also, each has a different number of children (zero, one, two, three, or four). Given the information in Box 11-2, figure out how many children the person who owns the Shetland sheepdog has.

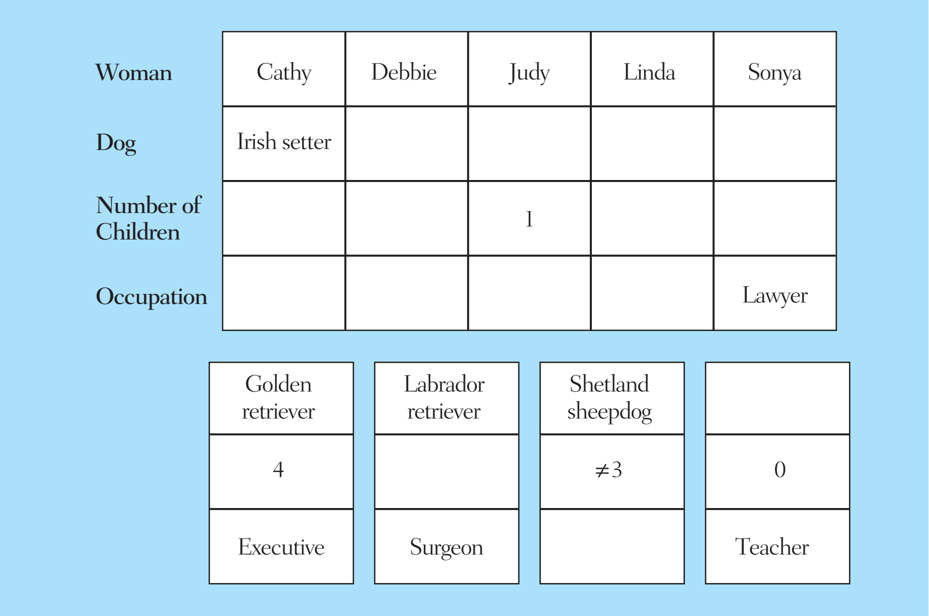
In solving a problem, you often need to make certain provisional assumptions. Sometimes they turn out to be wrong and need to be "unmade." In those instances, it is useful to have some means of keeping track of when and which assumptions were made so you can back up to certain points of choice and start over, a process known as **backtracking.** The women, dogs, children, and jobs

### Box 11-2 The Women, Dogs, Children, and Jobs Problem

From the following information, determine how many children the owner of the Shetland sheepdog has.

There are five women: Cathy, Debbie, Judy, Linda, and Sonya.
There are five occupations: clerk, executive, lawyer, teacher, and surgeon.
Everyone has a different number of children: 0, 1, 2, 3, or 4.
Cathy owns the Irish setter.
The teacher has no children.
The owner of the Labrador retriever is a surgeon.
Linda does not own the Shetland sheepdog.
Sonya is a lawyer.
The owner of the Shetland sheepdog does not have three children.
The owner of the golden retriever has four children.
Judy has one child.
The executive owns a golden retriever.
Debbie owns the Bernese mountain dog.
Cathy is a clerk.

**FIGURE 11-3** ■ *Partial solution to the women, dogs, children, and jobs problem.*



| Woman | Cathy | Debbie | Judy | Linda | Sonya |
|---|---|---|---|---|---|
| Dog | Irish setter | | | | |
| Number of Children | | | 1 | | |
| Occupation | | | | | Lawyer |

| | | | |
|---|---|---|---|
| Golden retriever | Labrador retriever | Shetland sheepdog | |
| 4 | | $\neq 3$ | 0 |
| Executive | Surgeon | | Teacher |

problem in Box 11-2 is a case in point. Many people solve such problems by setting up a chart like the one shown in Figure 11-3. The chart is incomplete, and corresponds to the chart of someone who has read only the first 11 lines of Box 11-2. At this point, a problem solver can determine that the golden retriever's owner, who is an executive with four children, is either Debbie or Linda. The problem solver might temporarily assume that it's Debbie, only to find out when he reads the 13th line in Box 11-2 that Debbie owns the Bernese mountain dog. He would enter that information into his chart. But if the problem solver backed up to the point at which he made the incorrect assumption (that is, knew that either Debbie or Linda was the golden retriever–owning, mother-of-four executive), he would now know it is Linda, and this information would be necessary to solve the rest of the problem.

The key to backtracking, then, is that the problem solver keep close track of choice points—places where she made a provisional assumption—so that, if subsequent work leads to a dead end, she can "back up" to that choice point and make a different assumption.

## Reasoning by Analogy

The next problem is famous in the literature and is known as "the tumor problem":

> Given a human being with an inoperable stomach tumor and rays that destroy organic tissue at sufficient intensity, by what procedure can one free him of the tumor by these rays and at the same time avoid destroying the healthy tissue that surrounds it?

Originally posed to participants by Duncker (1945, p. 1), the problem is often a difficult challenge. Duncker argued from studying the performance of several participants (Box 11-3 presents an example protocol) that problem solving is not a matter of blind trial and error; rather, it involves a deep understanding of the elements of the problem and their relationships. To find a solution, the solver must grasp the "principle, the functional value of the solution," first and then arrange the specific details. The solution to the tumor problem is to send weak rays of radiation (weak enough so that no individual ray will inflict damage) from several angles, such that all rays converge at the site of the tumor. Although the

## Box 11-3 Protocol From One of Duncker's (1945) Subjects

1. Send rays through the esophagus.
2. Desensitize the healthy tissues by means of a chemical injection.
3. Expose the tumor by operating.
4. One ought to decrease the intensity of the rays on their way; for example—would this work?—turn the rays on at full strength only after the tumor has been reached. (Experimenter: False analogy; no injection is in question.)
5. One should swallow something inorganic (which would not allow passage of the rays) to protect the healthy stomach-walls. (E: It is not merely the stomach walls which are to be protected.)
6. Either the rays must enter the body or the tumor must come out. Perhaps one could alter the location of the tumor—but how? Through pressure? No.
7. Introduce a cannula.—(E: What, in general, does one do when, with any agent, one wishes to produce in a specific place an effect which he wishes to avoid on the way to that place?)
8. (Reply:) One neutralizes the effect on the way. But that is what I have been attempting all the time.
9. Move the tumor around to the exterior. (Compare 6.) (The E repeats the problem and emphasizes ". . . which destroy *at sufficient intensity*.")
10. The intensity ought to be variable. (Compare 4.)
11. Adaptation of the healthy tissues by previous weak application of the rays. (E: How can it be brought about that the rays destroy only the region of the tumor?)
12. (Reply:) I see no more than two possibilities: either to protect the body or to make the rays harmless. (E: How could one decrease the intensity of the rays en route? [Compare 4.])
13. (Reply:) Somehow divert . . . diffuse rays . . . disperse . . . stop! Send a broad and weak bundle of rays through a lens in such a way that the tumor lies at the focal point and thus receives intensive radiation. (Total duration about half an hour.)

**SOURCE:** Duncker (1945, pp. 2–3).

radiation from any one ray will not be strong enough to destroy the tumor (or the healthy tissue in its path), the convergence of rays will be strong enough.

Gick and Holyoak (1980) presented participants with Duncker's tumor problem after each person had read a story such as the one in Box 11-4. Although the story appeared very dissimilar to the tumor problem, the underlying method of solution was the same. Gick and Holyoak found that participants who had read the story of the general *and* were told that it contained a relevant hint were more likely to solve the tumor problem than were participants who simply read the general story but did not have the analogy between the problems explicitly pointed out. The former group of participants were said to be using the problem-solving technique of **reasoning by analogy.**

The tumor problem and the problem of the general differ in their surface features but share an underlying structure. The components of one correspond at least roughly with the components of the other: The army is analogous to the rays; the capturing of enemy forces, to the destruction of the tumor; the convergence of soldiers at the fortress, to the convergence of rays at the site of the tumor. To use the analogy, participants must engage in the "principle-finding" analysis described by Duncker, moving beyond the details and focusing on the relevant structures of the problem. Gick and Holyoak (1980) referred to this process as the induction of an abstract *schema* (using the term in the ways defined in Chapters 6 and 7). They presented evidence that participants who

### Box 11-4 The Story of the General

A small country was ruled from a strong fortress by a dictator. The fortress was situated in the middle of the country, surrounded by farms and villages. Many roads led to the fortress through the countryside. A rebel general vowed to capture the fortress. The general knew that an attack by his entire army would capture the fortress. He gathered his army at the head of one of the roads, ready to launch a full-scale direct attack.

However, the general then learned that the dictator had planted mines on each of the roads. The mines were set so that small bodies of men could pass over them safely, since the dictator needed to move his troops and workers to and from the fortress. However, any large force would detonate the mines. Not only would this blow up the road, but it would also destroy many neighboring villages. It therefore seemed impossible to capture the fortress.

However, the general devised a simple plan. He divided his army into small groups and dispatched each group to the head of a different road. When all was ready he gave the signal and each group marched down a different road. Each group continued down its road to the fortress so that the entire army arrived together at the fortress at the same time. In this way, the general captured the fortress and overthrew the dictator.

**SOURCE:** Gick and Holyoak (1980, pp. 351–353).

construct such a representation are more likely to benefit from work on analogous problems.

It is interesting that participants often had to be explicitly told to use the story of the general to solve the tumor problem. Only 30% of participants spontaneously noticed the analogy, although 75% solved the problem if told that the story of the general would be useful in constructing the solution (for comparison, only about 10% solved the problem without the story). This is similar to a finding reported by Reed, Ernst, and Banerji (1974): Participants' performance was facilitated by their previous work on an analogous problem, but only if the analogy was pointed out to them.

In later work, Gick and Holyoak (1983) found that they could do away with explicit hints if they gave two analogous stories rather than one. Participants read the story of the general and a story about a fire chief's putting out a fire by having a circle of firefighters surround it, each one throwing buckets of water at once. Participants were told the experiment was about story comprehension and were asked to write summaries of each story and a comparison of the two before being given the tumor problem to solve. The authors proposed that providing multiple examples helps participants to form an abstract schema (in this case, what the authors called a "convergence" schema), which they later apply to new, analogous problems. Catrambone and Holyoak (1989) further suggested that unless participants were explicitly asked to compare stories, they did not form the necessary schema with which to solve the problem.

## ■ BLOCKS TO PROBLEM SOLVING

A problem, by definition, is something that can't be solved in a single, obvious step. For instance, we don't count combing our hair as an instance of problem solving because the step of using a comb does not require much thought and no particular obstacles need to be overcome.

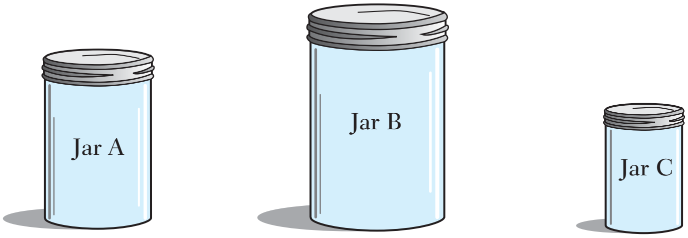
Problem solving, in contrast, carries the meaning of a goal with some barriers or constraints. Sometimes the barriers and constraints are so strong that they prevent, or at least seriously interfere with, successful solution. In this section, we will review some factors that apparently hinder problem solving on a variety of problems.

### Mental Set

Figure 11-4 presents a number of problems on the same theme: obtaining an exact amount of water, given three different-size measuring jugs. Before reading on, work on each problem in the order given, and write down the time it takes you to complete each one. Also, record any thoughts about the relative difficulty of the problems.

**FIGURE 11-4** ■ *The water jar problem.*

**SOURCE:** From Luchins (1942, p. 1).



| *Problem* | *Capacity of jar A* | *Capacity of jar B* | *Capacity of jar C* | *Desired amount* |
|---|---|---|---|---|
| 1 | 21 | 127 | 3 | 100 |
| 2 | 14 | 163 | 25 | 99 |
| 3 | 18 | 43 | 10 | 5 |
| 4 | 9 | 42 | 6 | 21 |
| 5 | 20 | 59 | 4 | 31 |
| 6 | 23 | 49 | 3 | 20 |
| 7 | 18 | 48 | 4 | 22 |
| 8 | 14 | 36 | 8 | 6 |

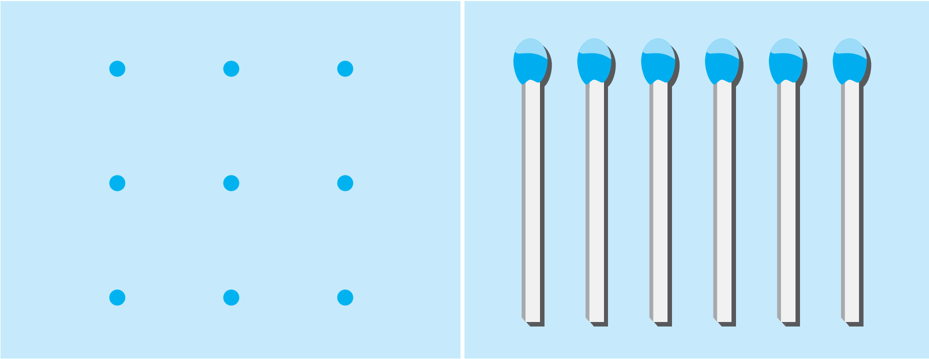
If you actually worked the problems, you probably found was the following: The first one took a relatively long time, but you were faster and faster at solving the subsequent problems, given the number of problems that you had previously worked. You also probably noticed a common pattern to the problems: All could be solved by the formula $B - A - 2C$. Did you use this formula to solve the second-to-last problem? If you did, that is interesting because an apparently more direct solution would be $A + C$. The very last problem is also interesting in that it does not fit the first formula at all but is quickly solved with a very easy formula, $A - C$. Did it take you some time to realize this? If so, your performance might be characterized as being constrained by *mental set*.

**Mental set** is the tendency to adopt a certain framework, strategy, or procedure or, more generally, to see things in a certain way instead of in other, equally plausible ways. Mental set is analogous to **perceptual set,** the tendency to perceive an object or pattern in a certain way on the basis of your immediate perceptual experience. Like perceptual set, mental set seems to be induced by even short amounts of practice. Working on several water jug problems in a row that follow a common pattern makes it easy to apply the formula but harder to see new relationships among the three terms.

Luchins (1942) reported on experiments in which problems such as those in Figure 11-4 were given to university students. After solving the first four problems using the formula $B - A - 2C$, all the students solved the fifth problem using this method, instead of the more direct $A + C$ method available. Even more striking, when the $B - A - 2C$ solution wouldn't work, students suffering

**FIGURE 11-5** ■ *The nine-dot and the six-matches problems.*

**SOURCE:** Goldstein (1994, p. 336).



Draw four straight lines that pass through each of the nine dots without removing your pencil from the paper.

Arrange six matches so that they form four triangles with all sides equal to the length of one match.

from mental set were unable to even see the more obvious $A + C$ solution, which would have worked!

Mental set often causes people to make certain unwarranted assumptions without being aware of making them. Figure 11-5 gives two examples. Most people, when asked to solve the famous nine-dot problem, make the assumption that the four lines must stay within the "borders" of the dots. Similarly, when given the six-matches problem, many people constrain themselves to creating the four triangles in a two-dimensional plane. These constraints make it impossible to come up with the solutions, shown in Figure 11-6.

Another problem relevant to mental set is borrowed from Perkins (1981). I will describe a situation, and you determine what the situation is:

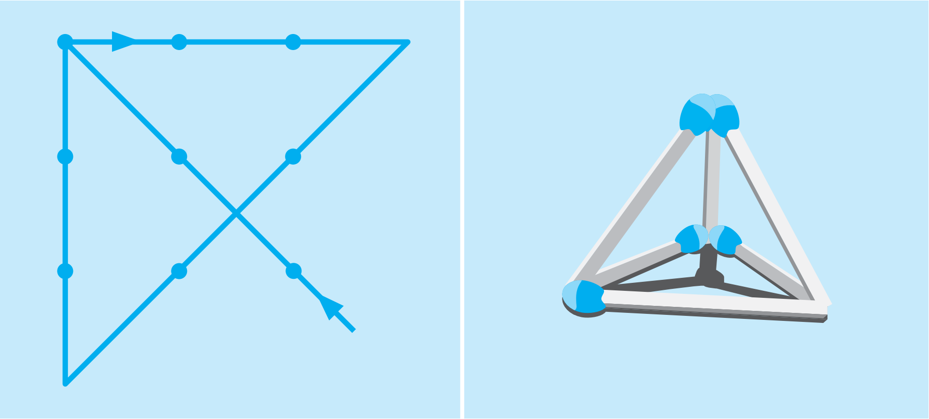
> There is a man at home.
>
> That man is wearing a mask.
>
> There is a man coming home.
>
> What is happening?

Because I can't interact with you, I'll report on the questions (constrained to be of the yes/no type) that my students ask when I present this. Is the man at home at his own home? *(Yes.)* Does the man at home know the other man? *(Yes.)* Does the man at home expect the other man? *(Yes.)* Is the mask a disguise? *(No.)* Is the man at home in a living room? *(No.)* Is the man at home in the kitchen? *(No.)*

Part of where my students start to go wrong is in making assumptions about the home in the situation. Many equate *home* with *house,* although the answer to the problem is a baseball game. Perkins (1981) would argue that the assumptions

**FIGURE 11-6** ■ *Answers to the nine-dot and the six-matches problems.*

**SOURCE:** Goldstein (1994, p. 338).



people make in interpreting the problem are a kind of mental set and that this mental set hinders problem solving.

Another example of mental set is illustrated in Figure 11-7, which depicts another famous problem in the literature, known as the two-string problem (Maier, 1930, 1931). A person is shown to a room that has two strings attached to the ceiling. The strings are spaced so far apart that the person can't hold onto both at the same time. His task is to tie these strings together somehow. All he has in the room with him are a table, a book of matches, a screwdriver, and a few pieces of cotton. What can he do?

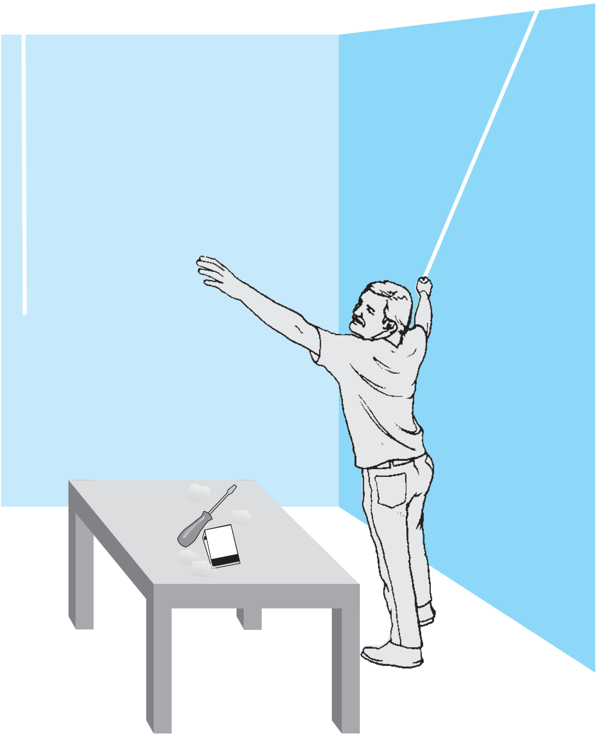
The solution, which many people have difficulty discovering, is to use the screwdriver as a weight to make one of the strings into a pendulum. Swing this string, walk to the other string and grab it, wait for the pendulum to swing toward you, grab it, and tie the two strings together. Fewer than 40% of the participants in Maier's experiment solved this without a hint. One source of difficulty seemed to be their unwillingness to think of other functions for a screwdriver; they failed to notice that the screwdriver could be used as a weight as well as for its intended function. This phenomenon is called **functional fixedness.** It appears to be an instance of mental set, in that a person subject to functional fixedness has apparently adopted a rigid mental set toward an object.

## Using Incomplete or Incorrect Representations

A related difficulty in problem solving has to do with the initial interpretation of the problem. If the problem is misunderstood, or if the wrong information is

**FIGURE 11-7** ■ *String problem. Two strings hang from the ceiling but are too far apart to allow a person to hold one and walk to the other. On the table are a book of matches, a screwdriver, and a few pieces of cotton. How could the strings be tied together?*

**SOURCE:** Weiten (1995, p. 310).

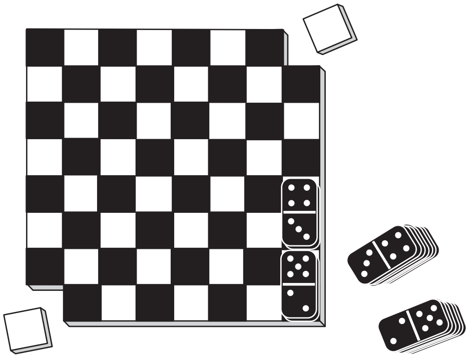


focused on, the solver is at a disadvantage. The checkerboard problem illustrates this block to problem solving.

The problem is depicted in Figure 11-8, which shows a standard checkerboard with two diagonally opposite corner squares cut off. Next to the checkerboard are a number of dominoes of such dimensions that each takes up exactly two checkerboard squares. Intact checkerboards, you'll recall, have 64 squares. This one has 62. Is there a way to arrange 31 dominoes such that every checkerboard square is covered by a domino?

The key to the solution is to realize that whatever the arrangement, each domino will cover exactly one black square and one red square, given the way checkerboards are arranged. But now notice that the two excised squares are the same color. Because a domino must cover two differently colored squares, there is no way to arrange 31 dominoes to cover the mutilated checkerboard.

**FIGURE 11-8** ■ *The mutilated checkerboard problem. Can 31 dominoes be arranged to cover the remaining checkerboard squares? Each domino covers two squares.*



The difficulty most people have with this problem is that they fail to include these two pieces of crucial information in their initial representation of the problem. Thus the representation is incomplete. Similarly, in the baseball game (man at home) problem given earlier, representing the problem in terms of a person sitting in a house would lead you down the wrong path. It would be a case of using an incorrect representation—one that included information not presented in the problem *and* not correct.

The choice of representation can often make a great difference. Schwartz (1971), studying problems such as the women-dogs-children-jobs problem of Box 11-2, found that people who constructed charts like the one in Figure 11-3 were much more successful in solving the problems than people who merely wrote down names, dogs, jobs, and so forth, with arrows or lines connecting them (for example, Cathy—Irish setter; Golden retriever—four children).

Here's another well-known example of a case which the form of the representation can make a problem either very easy or very hard. It's called the "numbers game," and the objective of each player is to choose from the set of digits enough to make an exact total of 15 from three digits. Two players are given a sheet of numbers, 1 2 3 4 5 6 7 8 9. They take turns crossing one of the digits off the list and adding it to their own list. The first player to have three digits totaling 15 (for example, 4, 5, 6; or 1, 6, 8) wins.

If you were to play this game, what would your strategy be? What if you played first, which digit would you choose? What if you played second, and your opponent had first chosen a 5? The first time or two you play this game, you might find it surprisingly challenging. Now look at Figure 11-9, which presents an alternative way of representing this game. Notice that, depicted this way, the difficult "numbers game" is actually the game of tic-tac-toe in disguise.

**FIGURE 11-9** ■ *A tic-tac-toe board representation of the numbers game.*

| | | |
|---|---|---|
| 6 | 7 | 2 |
| 1 | 5 | 9 |
| 8 | 3 | 4 |

Rendered as in Figure 11-9, the game is easy, but without this representation the problem is much harder to solve.

## Lack of Problem-Specific Knowledge or Expertise

Until now, we have been discussing general problem-solving abilities with problems that have a puzzlelike character. The assumption is that most of these problems are about equally unfamiliar to everyone and that people go about solving them in basically the same way. Other kinds of problems—for example, those in chess or other skilled games; textbook problems in physics, geometry, or electronics; computer programming; and problems in diagnosis—seem to be different in kind from the puzzles we have been talking about. In particular, experts and novices approach most such problems differently (Chi, Glaser, & Farr, 1988).

We saw in Chapter 3 that experts and novices differ in their perceptual abilities, with experts able to "pick up on" more perceptual information than a novice would. Effects of expertise are not limited to perceptual abilities, however. Familiarity with a domain of knowledge seems to change the way one solves problems within that frame of reference. A good example is to compare the ability of undergraduate psychology majors and their professors to design experiments. Typically, professors are much better at solving the problems connected to the task. Their experience in designing experiments lets them sort out the relevant from the irrelevant information and call to mind various situations that need to be noticed. It also provides a number of shortcut rules to use in estimating the number of participants to be used, the kinds of statistical analyses that can be performed, the duration of the experiment, and so on. Problem solvers who come to a problem with a limited knowledge base are clearly at a disadvantage.

A classic study of expert–novice differences was carried out by de Groot (1965). He examined the thinking processes of both chess masters and weaker players, finding that the master players considered about the same number of possibilities but somehow chose the best move more easily. Chase and Simon (1973), in a replication study, found that the more expertise a chess player had, the more information he extracted even from brief exposures to chessboards set up to reflect an ongoing chess game. That is, when a chess master and chess beginner are both shown a chessboard for 5 seconds, the chess master will remember more about where the pieces are placed—but only if the pieces are configured to depict a possible chess game.

Gobet and Simon (1996) examined the sophistication of play of Gary Kasparov, a Professional Chess Association world champion, as he played simultaneous games against four to eight opponents who were all chess masters. His opponents were each allowed 3 minutes per move (on average); Kasparov, one fourth to one eighth that amount of time for each game (because he was playing multiple games simultaneously). Despite the tremendous time constraints, Kasparov played almost as well as he did under tournament conditions, when facing only one opponent and having four to eight times as much time to think through and plan his moves. Gobet and Simon concluded that Kasparov's superiority came from his ability to recognize patterns more than from his ability to plan future moves. They based this conclusion on the fact that the time pressure of simultaneous games would severely hamper Kasparov's ability to think ahead, yet the overall quality of his play did not suffer.

Lesgold et al. (1988) compared the performance of five expert radiologists with that of first-, second-, third-, and fourth-year medical residents as they diagnosed X-ray pictures. They found the experts noted more specific properties of the X-ray films, hypothesized more causes and more effects, and clustered more symptoms together than did any of the nonexpert groups of medical residents.

Glaser and Chi (1988), reviewing this and other studies of expert–novice differences, described several qualitative distinctions between the two groups. First, experts excel in their own domains; that is, their knowledge is domain specific. A grand master chess player, for example, would not be expected to solve chemistry problems as well as a chemist would. We have already noted in Chapter 3 that experts perceive larger meaningful patterns in their domain of expertise than novices do. Experts are faster than novices at performing skills in their domain of expertise, and they show greater memorial abilities for information within that domain.

In problem solving, experts see and represent a problem in their domain at a deeper and more principled level than do novices, who tend to represent information superficially (Chi, Feltovich, & Glaser, 1981). For example, when solving physics problems, experts tend to organize the problems in terms of physics principles, such as Newton's first law of motion; novices instead tend to focus on the objects mentioned in the problem, such as an inclined plane or a frictionless surface. Experts also spend proportionately more time qualitatively analyzing a problem, trying to grasp or understand it, relative to novices, who are more likely to plunge in and start looking for solutions. Finally, throughout the process of problem solving, experts are more likely to check for errors in their thinking.

Expertise by itself is not always enough for problem solving, as shown dramatically in a case study of an experienced architect with a lesion to the right prefrontal cortex (Goel & Grafman, 2000). Patient P.F. was a 57-year-old architect who suffered a grand mal seizure and was treated for a stroke. Subsequent MRI scans showed a predominantly right-hemisphere lesion to the prefrontal cortex, a part of the brain previously implicated in deficits in the ability to plan and solve problems. Goel and Grafman asked P.F. (and a control architect, matched for age and education) to come to the lab to develop a new design for their lab space. Both P.F. and the control participant regarded this task as relatively easy.

P.F. was observed to have "his sophisticated architectural knowledge base . . . intact, and he used it quite skillfully during the problem structuring phase" (p. 415). However, P.F. was unable to move from this phase to the problem-solving phase, was unable to generate a preliminary design until two thirds of the way through the two-hour session, and created an erratic and minimal preliminary design that was never developed or detailed. These authors concluded that preliminary designs represent ill-structured problem solving (of the type described at the beginning of the chapter), and that P.F.'s lesion "has resulted in a selective impairment of the neural system that supports ill-structured representations and computations" (p. 433).

## ■ THE PROBLEM SPACE HYPOTHESIS

Researchers studying problem solving often think about the processes in terms of mentally searching a problem space (Baron, 1994; Lesgold, 1988; Newell, 1980; Newell & Simon, 1972). The main idea behind this **problem space hypothesis** is that every possible state of affairs within a problem corresponds to a node in a mental graph. The entire set of nodes occupies some mental area, and this area, together with the graph, is the problem space.

**FIGURE 11-10** ■ *A generic problem space.*

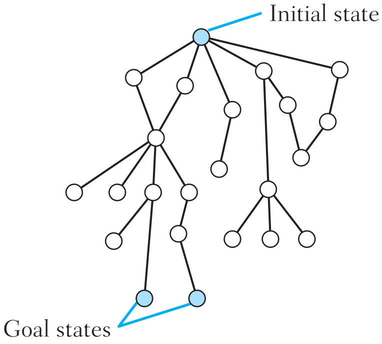


Figure 11-10 presents a schematic diagram of a generic problem space. Each circle, or node, corresponds to a certain state of affairs at some point during the problem-solving process. If the problem is to win a chess game, for example, each node corresponds to a possible chessboard configuration at each point in the game. The node labeled "initial state" corresponds to the conditions at the beginning of a problem—for example, a chessboard before the first move. The goal states correspond to conditions when the problem is solved—for example, configurations in which a game is won. Intermediate states (unlabeled in this diagram) are depicted by the other nodes.

If it is possible to move from one state to another by means of some operation, that move can be depicted in any paper-and-pencil representation of the problem space by a line connecting the two nodes. Any sequence of "mental moves" is shown as a sequence of moves from one node to another. Any sequence of moves beginning at the initial state and ending at the final goal state constitutes a path through the problem space. Figure 11-11 depicts a generic solution path; Figure 11-12 depicts a part of the problem space for the Towers of Hanoi problem.

Good problem solving is thought to be the creation of efficient paths: ones that are as short as possible and take as few detours as possible between the initial state and the goal state. It is assumed the best paths are found through searching, with thorough searches being more likely to turn up solutions.

Researchers in the field of artificial intelligence have created different search algorithms to search through problem spaces (Nilsson, 1998; Winston, 1984). One is depth-first search, which goes as far down a graph as it can to search for a goal state, before backing up to examine alternatives. Another is breadth-first search, which examines all nodes at a given level to search for a goal state before delving deeper into the graph. Different algorithms have

**FIGURE 11-11** ■ *A solution path through the problem space.*

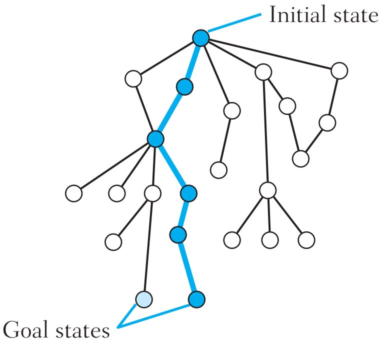
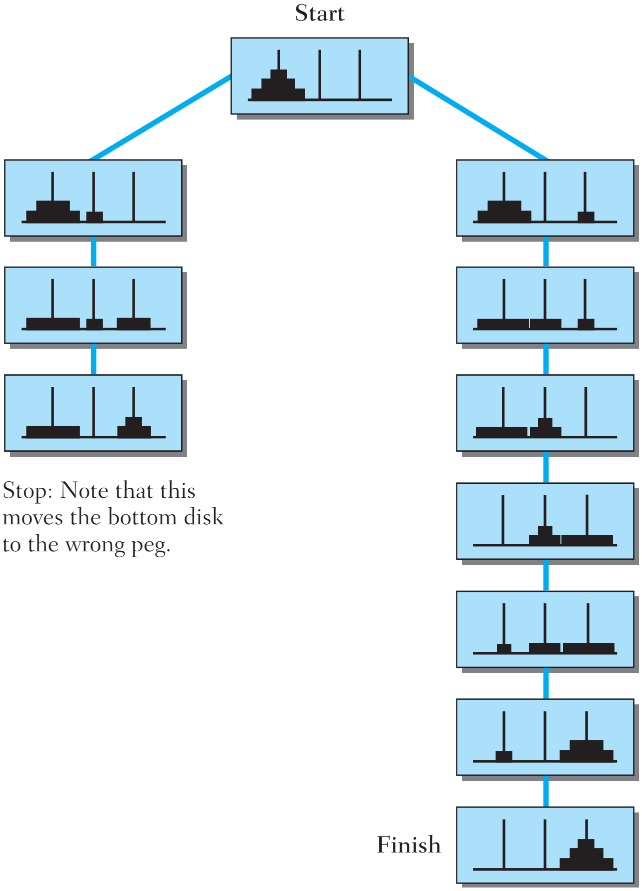


**FIGURE 11-12** ■ *A part of the problem space for the Towers of Hanoi problem, showing the solution.*


Start
Stop: Note that this moves the bottom disk to the wrong peg.
Finish

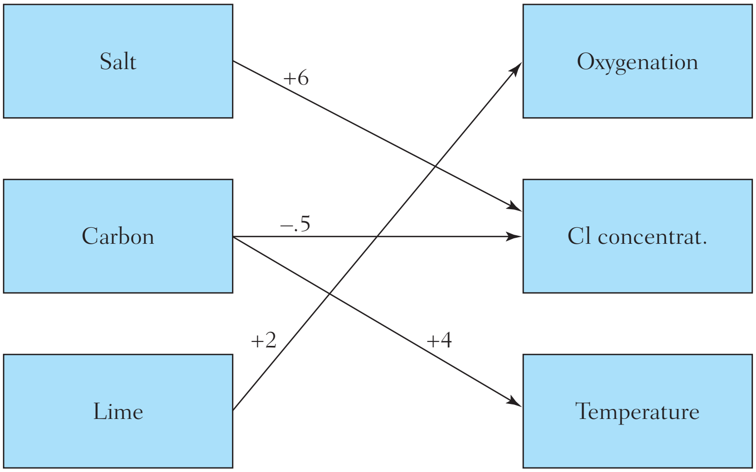
different probabilities of success depending on the nature of the graph, of course.

A study by Burns and Vollmeyer (2002) yielded some nonintuitive findings relevant to the idea of searching through problem spaces to generate solutions. These authors believed that exploration of a problem space would yield better performance. Moreover, they believed, exploration was more likely when the process was not curtailed by a person's eagerness to achieve a specific goal.

Burns and Vollmeyer (2002) used a task depicted in Figure 11-13. Participants were asked to imagine that they worked in a laboratory and that they were trying to figure out how to control various inputs to achieve a certain water quality effect. They could work at this task by changing inputs (salt,

**FIGURE 11-13** ■ *The water-tank system (note that Cl concentrat. is the chlorine concentration output).*

**SOURCE:** Burns and Vollmeyer (2002, p. 245).



carbon, lime) and observing what happened to the outputs (oxygenation, chlorine concentration, temperature). In reality, the inputs had linear relationships showing in the figure—for example, a change in the salt input produced an increase in the chlorine concentration—but participants were not told what the relationship between input and output was.

All participants were told they would eventually be asked to achieve a certain goal in terms of specific values for the outputs. Some of the participants (called “specific goal” participants) were given the specific goal at the start of the task, but told they wouldn’t have to achieve this goal until after an exploration period; others (called “nonspecific goal” participants) weren’t told what the goal was until after the exploration period. After the exploration phase, all participants were given a diagram similar to Figure 11-13, but without any of the links shown, and were asked to draw links between inputs and outputs, placing directions and weights on the links if they thought they knew them. From this, the researchers derived a “structure score” to calculate a participant’s degree of knowledge about the correct values of the links’ directions and weights.

Nonspecific goal participants received higher structure scores than specific goal participants. Both groups performed equivalently when asked to achieve specific goal values for the outputs, but nonspecific goal participants performed better on a transfer problem with new goal values than did specific goal participants. Burns and Vollmeyer (2002) did a follow-up study in which participants in both conditions were asked to think aloud as they performed the task. These results indicated that nonspecific goal participants were more likely to test specific hypotheses during the exploration phase. Presumably, having a specific goal can cut down on the amount of effort devoted to searching the problem space, in Newell and Simon's terminology.

The problem space hypothesis can also be recruited to help us understand how blocks to problem solving work. Searches that fail to explore parts of the space (because of mental set, for example) can block problem solving when the solution lies in a part of the space that isn't searched. Incomplete or incorrect representations are likely to result in the construction of an incomplete or incorrect problem space, which in turn also harms problem solving.

The acquisition of expertise is another way of exploring problem spaces. Expertise presumably allows people to develop better hunches about which areas of the problem space will be most useful to explore, and in what order.

## EXPERT SYSTEMS

The problem space hypothesis has been used to create **expert systems,** computer programs designed to model the judgments of one or more human experts in a particular field. Expert systems contain a knowledge base, which stores facts relevant within that field. They typically also contain a set of **inference rules** (of the form "If *X* is true, then *Y* is true"), a search engine that the program uses to search the knowledge base using the inference rules, and some interface, or means of interacting with a human user who has a question or problem for which he or she is consulting the expert system (Benfer, Brent, & Furbee, 1991).

One example of an expert system is MUckraker, an expert system designed to give advice to investigative reporters regarding the best way to approach people for interviews, to prepare for interviews, and to examine public documents while investigating an issue (Benfer et al., 1991). Table 11-1 presents some (simplified) rules MUckraker uses to give advice on how to approach a person for an interview.

The format of the rules used includes several antecedents, or conditions. Rule 2, for example, has three antecedents: (a) The probable source will not talk by telephone with the reporter; (b) the interview is crucial; and (c) there are more than six days in which to get the interview. Each of these antecedents specifies a condition that must be met for the rule to be activated.

Rules also have a consequent part, indicated by the word THEN. These consequents are actions to be taken if the rule is applied. For example, the action of Rule 2 is to set a variable (send_by_mail$_2$) to a certain value (namely, 80). Some rules also include an explanation or justification, preceded by the word BECAUSE. Notice the references to "send_by_mail$_1$," "send_by_mail$_2$,"

## Table 11-1 Simplified Examples of Rules From MUckraker

**Rule 1: Prefer_mail**
IF unknown whether source will talk
with reporter on telephone
AND the interview is critical
AND there are > 6 days to get the
interview

THEN (send_by_mail)$_1$ request = 60
ELSE telephone request = 40
BECAUSE may get the interview with
a formal, written request.

**Rule 2: Definitely_prefer_mail**
IF probable source will not talk with
reporter on telephone
AND the interview is critical
AND there are > 6 days to get the
interview

THEN (send_by_mail)$_2$ request = 80
BECAUSE see Rule 1.

**Rule 3: Telephone_anyway**
IF probable source will not talk with
reporter on telephone
AND if the interview is not-critical
OR there are < 6 days to get the
interview

THEN (send_by_mail)$_3$ request = 10
BECAUSE there isn't time for mail
AND telephoning worth a try.

**Rule 4: Older_sources**
IF the age of the source is > 49 years
AND the interview is critical
AND there are > 6 days to get the
interview

THEN (send–by–mail)$_4$ request = 90
BECAUSE older individuals respond
more positively to written requests.

**Rule 5: Combine_Send_by_mail**
IF **maximum** of (send_by_mail)$_i$ > 79

THEN send written request and ASK:
Do you want to see a sample letter?
ELSE telephoning worth a try
BECAUSE most sources will talk to a
reporter on the telephone.

**Source:** Benfer et al. (1991, p. 6).

and so forth. These are names of variables used by the program. Rules 1 through 4 assign values to send_by_mail$_1$ through send_by_mail$_4$, respectively. Rule 5 checks to see whether any of these four variables have been assigned a value greater than 79. If so, Rule 5 directs the reporter to send the potential interviewee a request by mail.

Creating expert systems is a complex undertaking. Typically, one or more human experts in the domain are interviewed, often repeatedly. They are often asked to generate a verbal online protocol, thinking aloud as they classify instances or solve problems (Stefik, 1995). Part of the difficulty comes from the fact that it is difficult for any expert to state all of his or her knowledge.

For example, you are probably "expert" at studying for academic exams, right? Suppose I simply asked you to state all your knowledge that pertains to the activity of studying for an exam. Hard to do, isn't it? Expert system developers therefore often find themselves adopting techniques from anthropologists. They follow experts around as they "do their thing," often asking them to elaborate on their thinking as it happens (Benfer et al., 1991). Through repeated interviews, the developers are able to formulate rules such as those shown in Table 11-1.

Why would anyone *want* to develop computerized expert systems and use them in place of human experts? One reason may be that the supply of highly trained human experts is limited in many domains. Not every city, for example, has an expert in every domain, and if the knowledge possessed by experts can be distributed through software, the wealth is spread.

A second argument will be further elaborated in Chapter 13. There we will see that human decision making is often, if not always, tainted by biases, some quite insidious. Especially when a problem is complex, with many factors, the cognitive load placed on the person facing the problem can quickly become overwhelming. Having an expert system means gaining a handle on the complexity, and stopping it from crushing the process of finding the best solution.

## ■ FINDING CREATIVE SOLUTIONS

Many of the problems psychologists ask people to solve require *insight,* a change in frame of reference or in the way elements of the problem are interpreted and organized. The process by which insight occurs is not well understood. Whatever it is, it appears to play a vital role in what is commonly called **creativity.** Although the term is difficult to define precisely, many psychologists agree that creativity has to do with appropriate novelty—that is, originality that suits some purpose (Hennessey & Amabile, 1988; Runco, 2004). Appropriate ideas that lack novelty are mundane; conversely, original ideas that do not address some problem in a useful way are bizarre. Other cognitive scientists talk of creativity as consisting of a combination, or recombination, of knowledge, information, or mental representations—things the creator "already has," knows of, or has depicted (Dartnall, 2002).

Great artistic, musical, scientific, or other discoveries often seem to share a critical moment, a mental "Eureka" experience when the proverbial "lightbulb" goes on. Many biographies of composers, artists, scientists, and other eminent experts begin with "Eureka" stories (Perkins, 1981, presented a review of some of these). Such stories lead to the notion that creative people have something that less creative people don't have or that their cognitive processes work in very different ways (at least while they are being creative) from those of less creative people.

In this section, we will focus on two types of explanations for creative insight: one that describes creativity as special cognitive processing and one that describes it as the result of normal, everyday cognition.

## Unconscious Processing and Incubation

As a college junior, I took courses in calculus, which, although extremely useful, were often extremely frustrating to me. I would work on a homework assignment, only to find one of the problems absolutely unworkable. The problem would nag at me, and I'd try every technique I could think of. In frustration, I would put the problem aside and go on to other things. Late that night, sometimes waking from sleep, I would see the problem in a whole new light. Often I had discovered the correct solution. (On occasions when I'd hit on another incorrect solution, my feelings of frustration were renewed.)

The experience I am describing is a "textbook case" of **unconscious processing,** or **incubation.** The idea is that while my mind was actively running other cognitive processes, some other sort of processing was happening in the background. (Those of you who like computer metaphors might describe this as "batch processing" as opposed to "interactive processing.") The unconscious processing churned away, even as I slept, until the answer was found; then the answer announced itself all at once, even if it had to wake me from a sound sleep. Those who believe in incubation typically believe in the existence of an unconscious layer of the mind that can process information without giving rise to conscious awareness.

Smith and Blakenship (1989) offered one empirical demonstration of incubation effects by means of picture-word puzzles called *rebuses.* After the participants had solved 15 rebuses, they were presented with a 16th, which had a misleading cue that induced fixation on an incorrect interpretation. They were later given this critical rebus a second time, without the cue, and were again asked to solve the puzzle and also to recall the cue. Control participants saw the second presentation of the rebus immediately, but experimental participants received either a 5- or 15-minute "break" from the puzzle, during which they either did nothing or were asked to complete a demanding music perception task (to prevent them from continuing to work on the rebus surreptitiously). The authors predicted that those who were given longer "filled" intervals (during which the music task was presented) would be more likely to forget the misleading cue and thus to solve the rebus. In fact, this pattern of results is exactly the one they report.

Most empirical studies, however, fail to find positive effects of incubation: Participants who take physical and mental breaks during problem solving, and who therefore have more opportunity for incubation, rarely show increased ability to solve problems more thoroughly or more quickly than participants who work steadily at the problem (Olton, 1979). Moreover, participants in another study on incubation effects reported that during the "break" periods they surreptitiously thought aloud about the problem. In fact, participants in another experimental condition who during the break were prevented from this covert thinking about the problem (by having them memorize a text passage) showed very few effects of incubation (Browne & Cruse, 1988).

Designing critical tests of the incubation hypothesis is very difficult: Experimenters must make sure participants really do cease thinking about the problem during the incubation interval, a challenging task for experimenters who cannot read minds!

## Everyday Mechanisms

Does creative insight depend on special cognitive processes, such as incubation? An alternative view asserts that it results from ordinary cognitive processes that virtually every person uses in the normal course of life (Perkins, 1981). Perkins's ideas provide a coherent overview of this approach to the study of creativity and will be reviewed in detail here. Other authors offer slightly different proposals but share Perkins's idea that the processes leading to creativity are not extraordinary (Langley & Jones, 1988; Sternberg, 1988; Ward, Smith, & Finke, 1999; Weisberg, 1988).

Perkins (1981) described examples of cognitive processes that underlie normal everyday functioning as well as creative invention. One such process is *directed remembering*. This is the ability to channel your memory in order to make conscious some past experience or knowledge that meets various constraints. The first task in this chapter, asking you to think of foods and drinks whose names begin with *c,* is a directed-remembering task. Perkins argued that the same process goes on in creative invention. Darwin's construction of evolution theory, for instance, had to provide an explanation consistent with existing scientific knowledge. That knowledge constrained the types of explanations he could invent.

A second relevant cognitive process is *noticing*. An important part of creation, artists and scientists assert, is revising drafts. In revising, one needs to notice where the problems are. Noticing also plays a role in many "Eureka!" or "Aha!" experiences, according to Perkins, when creators notice a similarity between one problem and another.

*Contrary recognition,* or the ability to recognize objects not for what they are but as something else, is another important creative process. Seeing a cloud as

Nancy J. Ashmore

*Perkins argues that creative people rely on ordinary cognitive processes when they create.*

a castle is a familiar example. This ability obviously relates to analog thinking in that it requires the creator to move beyond the bounds of reality, of what is, and to imagine reality in other ways.

This approach to creativity, then, assumes that creative individuals use the same cognitive processes that so-called noncreative people use. Its proponents argue that "flashes of insight" actually occur in a progressive, step-by-step fashion. Incubation, following this line of argument, has to do with making a fresh start on the solution process, forgetting old approaches that did not work. Note that this description is quite similar to descriptions of what it means to break a mental set.

Indeed, the relationship between problem solving and the contrary recognition approach to creativity is strong. Both include the idea of a mental search for possibilities that are novel and that meet various requirements or constraints. A person's creativity has to do with her willingness to search harder and longer for solutions that meet multiple constraints. What makes for creativity, then, are a creator's own values for original, useful results; her ability to withstand potentially long periods without success; and her plans and abilities.

Many proposed accounts of creativity remain, for the most part, untested empirically. Thus the question of whether acts of creativity use special-purpose or regular cognitive processes remains open, as researchers struggle to develop appropriate empirical methods to investigate creativity (Runco & Sakamoto, 1999). The proposals just described, then, should be seen as ideas that can guide future investigations rather than as well-developed theories that have survived rigorous testing.

## ■ CRITICAL THINKING

Much creativity hinges on people's abilities to generate a number of ideas that might at first seem "off the wall" or "out of touch." Once a novel idea is generated, however, it must be evaluated and assessed in terms of its appropriateness. Does the proposed solution really meet all the objectives and constraints? Are there hidden or subtle flaws in the idea? What are the proposal's implications?

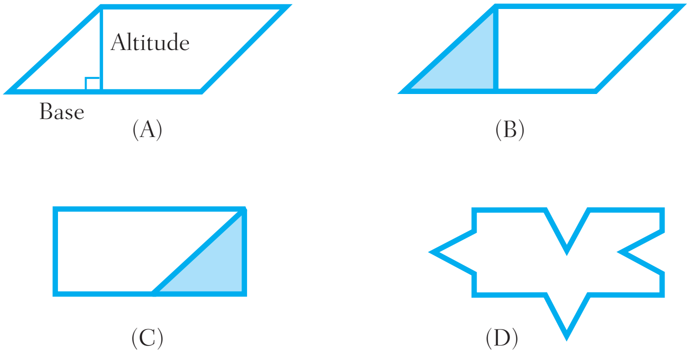
A person asking these kinds of questions can be described as doing what psychologists, philosophers, and educators call **critical thinking.** Many definitions of critical thinking exist. Dewey (1933), who called it "reflective thinking," defined it as "active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends" (p. 9). Dewey distinguished between reflective thought and other kinds: random ideas, rote recall, beliefs for which a person has no evidence.

Wertheimer (1945), a Gestalt psychologist, presented several examples that illustrate critical thinking quite well. One concerns learning how to find the area of a parallelogram. A way to teach someone to do this is to teach a formula, such as the familiar one from high school geometry: Area = Base × Altitude. Figure 11-14(A) presents an example of a parallelogram, with the base and altitude labeled.

If the student memorizes this formula carefully, he or she will have a "rote" means, or what Wertheimer called a "mechanically repetitive" means, of solving the problem. One problem with rote solutions, however, is that if a student forgets the formula, he may be at a complete loss. A better approach, Wertheimer argued, is to try to teach the student to grasp the "essential structure" of the problem—to identify and understand the fundamental issues.

Consider the parallelogram in Figure 11-14(B), noting the shaded area. Suppose this area is cut off the parallelogram and added to the other side, as shown in Figure 11-14(C). The transformation of the object creates a familiar and simple geometric object, a rectangle. The formula for finding the area of a rectangle is well known (Base × Altitude). Note that the transformation has

**FIGURE 11-14** ■ *Parallelograms and another geometric figure.*



added exactly the same area to the right side of the figure as was subtracted from the left. As a result, the total area has not been changed. Instead, a more "regular" geometric figure, with exactly the same area, has been created.

What is the advantage of teaching this method of solution? For one thing, it is more generalizable. The method applies not just to parallelograms but to many geometrically irregular figures, such as the one depicted in Figure 11-14(D). For another, the solution shows a deeper understanding of *why* the formula works. In this instance, the formula is not simply blindly applied to the problem but rather grows out of the student's understanding of the nature of a parallelogram as a geometric object.

In a more recent study of critical thinking, David Perkins and his colleagues (Perkins, Allen, & Hafner, 1983) presented students and adults of various levels of educational background with various controversial issues. Participants were asked to reason aloud about each issue. One example was "Would a law requiring a five-cent deposit on bottles and cans reduce litter?" (Perkins et al., 1983, p. 178). The authors measured critical thinking by looking at the number of times a participant raised objections or challenges to his own thinking. An example of what they would consider good critical thinking is the following:

> The law wants people to return the bottles for the five cents, instead of littering them. But I don't think five cents is enough nowadays to get people to bother. But wait, it isn't just five cents at a blow, because people can accumulate cases of bottles or bags of cans in their basements and take them back all at once, so probably they would do that. Still, those probably aren't the bottles and cans that get littered anyway; it's the people out on picnics or kids hanging around the street and parks that litter bottles and cans, and they wouldn't bother to return them for a nickel. But someone else might. (p. 178)

Notice the structure of the thinking here: Each sentence in some way presents an objection to the previous one.

According to Perkins, good thinking requires a large knowledge base and some means of using it efficiently. Good thinking also requires the kind of objection-raising just illustrated, showing the thinker actively trying to question him- or herself and to construct examples and counterexamples to his or her conclusions. What often hampers critical thinking is a kind of mental laziness—stopping thinking whenever you get any answer at all. An uncritical thinker might reason about the bottle bill as follows: "Well, it'd be nice to try to reduce litter, but five cents won't motivate people, so it won't work." Notice that in this case the person constructs one mental scenario, then stops, without questioning any of the assumptions or trying to think of any other possibilities. Perkins et al. (1983) urged people to overcome this tendency to think about an issue only until things make superficial sense and, instead, to search harder and look longer for other possibilities and interpretations.

## SUMMARY

1. Thinking, the manipulation of information, occurs for a wide range of what appear to be very different tasks. Psychologists draw distinctions among types of problems (for example, between well-defined and ill-defined ones) and among types of thinking (for example, focused versus unfocused). It is not yet clear, however, whether the cognitive processes used for different tasks are themselves really different in kind. An alternative possibility is that what look like different kinds of thinking really stem from different combinations of the same cognitive processes.
2. Some psychologists studying problem solving have discovered general strategies (for example, generate-and-test, means–ends analysis, reasoning by analogy) that they believe people use in a wide variety of situations and have explored different blocks to problem solving (mental set, functional fixedness, incorrect or incomplete problem representations).
3. Other psychologists argue for the importance of domain-specific knowledge and strategies as a better predictor of whether a given person will have success solving a given problem. These investigators point out that problem-solving strategies often vary with the expertise, or background knowledge, of the problem solver.
4. Similarities among kinds of thinking can also be identified. Some psychologists argue that the similarities can be explained by a common framework: the idea that all sorts of instances of thinking (including episodes of problem solving, inventing, and even reasoning and decision making, covered in Chapters 12 and 13) are all a kind of mental search (Baron, 1994). This proposal accepts the problem space hypothesis, or something close to it, as a good account of how people mentally

manipulate information. The problem space hypothesis views thinking as finding a path through a "mental graph" of possibilities (the mental graph being the problem space). Sometimes the search for a path is very focused and constrained; at other times (for example, during episodes of daydreaming), it meanders without a definite goal.

5. Expert systems, computer programs designed to mimic a human expert in a specific field, are one kind of instantiation of a problem space. Expert systems contain a knowledge base, inference rules, some means of searching through the knowledge base, and a user interface so that the human user can ask questions and be queried to provide the program with more information.
6. Psychologists studying creativity differ over whether there is one general creativity, independent of domain, or whether creativity, like expertise, is specific to a domain. Some argue for special-purpose creative cognitive processes, such as incubation and unconscious processing; others believe that creativity makes use of everyday, ordinary cognitive processes such as directed remembering and contrary recognition.
7. Some psychologists have argued that the factors that seem to promote good performance on one type of thinking task also seem to help on others. Among these factors are remaining open-minded, exploring unusual possibilities, questioning the first conclusion you come to, trying to avoid bias, and trying to find new and fresh approaches.
8. Although no one would argue that thinking skills can substitute for a broad and deep knowledge base, what is suggested is that good thinking skills help you get the most out of the knowledge you have. This suggestion, based largely on anecdotal proposals from educators, philosophers, and psychologists, awaits future research on the processes used in all kinds of thinking.

## REVIEW QUESTIONS

1. Do well-defined and ill-defined processes make use of the same cognitive processes? How might psychologists go about trying to answer this question?
2. Compare and contrast the generate-and-test, the means–ends analysis, and the reasoning-by-analogy approaches to problem solving.
3. What might the Gick and Holyoak results on reasoning by analogy suggest about people applying theoretical principles in real-world situations? Explain.
4. In what ways is mental set a phenomenon similar to perceptual set (described in Chapter 3)? In what ways are the two phenomena dissimilar?
5. Describe some of the expert–novice differences in problem solving.
6. Discuss the problem space hypothesis. How might it account for and explain the various blocks to problem solving?

7. Explore the connections and differences in problem solving reviewed in the chapter.
8. What kinds of cognitive processes have been proposed to account for creativity? How can an experimental psychologist test the role of any one of these processes?

## KEY TERMS

backtracking
creativity
critical thinking
expert system
functional fixedness
generate-and-test technique
GPS (General Problem Solver)
ill-defined problem
incubation
inference rule
introspection
means–ends analysis
mental set
perceptual set
problem solving
problem space hypothesis
reasoning by analogy
thinking
unconscious processing
well-defined problem
working backward

## CogLab DEMONSTRATIONS

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

## WEB RESOURCES

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

## CHAPTER 12

# Reasoning

**Types of Reasoning**
- Deductive Reasoning
- Inductive Reasoning
- Everyday Reasoning

**Patterns of Reasoning Performance**
- Effects of Premise Phrasing
- Alteration of Premise Meaning
- Failure to Consider All Possibilities
- Content and Believability Effects
- Biases

**Three Approaches to the Study of Reasoning**
- The Componential Approach
- The Rules/Heuristics Approach
- The Mental Models Approach

**Neuropsychological Evidence on Reasoning**

It is six o'clock, and you've been waiting for more than an hour for your friend to arrive for dinner. She's almost always on time, and she's the kind of person who would call if she knew she'd be late. You remember her telling you she would be driving her car to get to your place. Putting all this information together, you conclude that, more than likely, she's caught in traffic. Psychologists use the term *reasoning* to describe these and other cognitive processes "that [transform] given information (called the set of **premises**) in order to reach conclusions" (Galotti, 1989, p. 333).

The term *reasoning* is often used interchangeably with the term *thinking*, and you may therefore notice a great deal of overlap between the topics covered in this chapter and those covered in Chapter 11, "Thinking and Problem Solving." The psychologists who do make a distinction between reasoning and thinking see the first as a special case of the second. Specifically, when cognitive psychologists speak of reasoning, they mean a specific kind of thinking: the kind done in solving certain kinds of puzzles or mysteries. Reasoning often involves the use of certain principles of logic. At other times, the term is used more broadly, to cover instances of thinking in which people take certain information as input and, by making various inferences, either create new information or make implicit information explicit.

When reasoning, we have one or more particular goals in mind—our thinking is focused. Reasoning involves inferences or conclusions drawn from other information. Some of the conclusions we draw involve new information; however, many are so mundane that we may not even notice we have done any mental work to draw them. For instance, a friend says to you, "Last night at softball, I managed to catch a pop fly." From this, you almost automatically infer that your friend in fact tried to catch that ball. Her word *managed* presupposes effort on her part, and this presupposition cues your inference. All this happens so quickly and automatically that you would probably not even notice you had drawn an inference. In fact, you took your friend's statement (the premise) and drew the conclusion you did on the basis of your understanding of the words in the premise and their presuppositions.

Psychologists studying reasoning often give people logical puzzles to solve. One of my favorite examples (based on the *Alice in Wonderland* stories) is shown in Box 12-1. Try to solve it on your own before comparing your thinking with the solution, which is laid out at the end of the chapter. In these kinds of tasks, the inferences people draw often follow principles of formal logic. This tendency has led some cognitive psychologists to develop a "psychologic," or set of logical principles that they believe people rely on to draw inferences. We will give examples of such systems later.

Other psychologists have noted, however, that some situations that require inferences do not have logical principles that apply. For example, consider the following **analogical reasoning** task: Washington is to one as Jefferson is to what? It seems unlikely that any general rule will apply to this problem and likely that drawing the correct inference will depend on your knowledge of U.S. presidents and either their serial order of office (Washington was the first president, Jefferson the third) or their appearance on U.S. paper currency (Washington on the one-dollar bill, Jefferson on the two-dollar bill).

We will examine a variety of reasoning tasks in the upcoming sections. To describe people's performance, you will first need to understand something about logical principles and arguments and kinds of reasoning tasks. These will be reviewed in the next section. We will also examine some factors that seem to hinder reasoning performance and cause people either to draw erroneous conclusions or to overlook counterexamples and exceptions to the conclusions they draw. Finally, we will examine three general frameworks that attempt to explain the mental processes we use when we draw inferences and conclusions.

## Box 12-1 A Logic Puzzle

“How about making us some nice tarts?” the King of Hearts asked the Queen of Hearts one cool summer day.

“What’s the sense of making tarts without jam?” said the Queen furiously. “The jam is the best part!”

“Then use jam,” said the King.

“I can’t!” shouted the Queen. “My jam has been stolen!”

“Really!” said the King. “This is quite serious! Who stole it?”

“How do you expect me to know who stole it? If I knew, I would have had it back long ago and the miscreant’s head in the bargain!”

Well, the King had his soldiers scout around for the missing jam, and it was found in the house of the March Hare, the Mad Hatter, and the Dormouse. All three were promptly arrested and tried.

“Now, now!” exclaimed the King at the trial. “I want to get to the bottom of this! I don’t like people coming into my kitchen and stealing my jam!” . . .

“Did you by any chance steal the jam?” the King asked the March Hare.

“I never stole the jam!” pleaded the March Hare. . . .

“What about you?” the King roared to the Hatter, who was trembling like a leaf. “Are you by any chance the culprit?”

The Hatter was unable to utter a word; he just stood there gasping and sipping his tea.

“If he has nothing to say, that only proves his guilt,” said the Queen, “so off with his head immediately!”

“No, no!” pleaded the Hatter. “One of us stole it, but it wasn’t me!”

“And what about you?” continued the King to the Dormouse. “What do you have to say about all of this? Did the March Hare and the Hatter both tell the truth?”

“At least one of them did,” replied the Dormouse, who then fell asleep for the rest of the trial.

As subsequent investigation revealed, the March Hare and the Dormouse were not both speaking the truth.

Who stole the jam?

**SOURCE**: Smullyan (1982, pp. 7–8).

## TYPES OF REASONING

Cognitive psychologists, along with philosophers, draw many distinctions between kinds of reasoning. One common distinction divides reasoning into two types: deductive and inductive. There are several ways to explain this distinction. One way of thinking about the difference is to say that **deductive reasoning** goes from the general to the specific or particular (for example, “All college students like pizza; Terry is a college student; therefore, Terry likes pizza”). **Inductive reasoning** goes from the specific to the general (for example, “Brian is a college student; Brian lives in a dormitory; therefore, all college students live in dormitories”).

Another way to describe the difference between the two types of reasoning is to say that in deductive reasoning, no new information is added; any conclusion drawn represents information that was already implicit in the premises. Inductive reasoning, in contrast, can result in conclusions that contain new information.

A third, related way of talking about the differences between deductive and inductive reasoning has to do with the claims that can be made for the kinds of conclusions drawn. Deductive reasoning, if performed correctly, results in conclusions that are said to have **deductive validity** (Skyrms, 1975). An argument is deductively valid if and only if it is impossible for the premises to be true and the conclusion (or conclusions) to be false. Deductive validity thus provides the reasoner with a nice guarantee: Start with true premises and reason according to logical principles, and the conclusion you come to cannot be false. The argument about Terry and the pizza is a deductive argument: If it is true that all college students like pizza and that Terry is a college student, then we know, with absolute certainty, that Terry likes pizza.

It would be very nice, in many ways, if all kinds of reasoning resulted in guaranteed conclusions. However, deductive validity is a property that holds only for deductive reasoning. Many kinds of reasoning are inductive rather than deductive, and in these cases we cannot be certain of our conclusions; we can have only stronger or weaker confidence in them. Take the argument about Brian’s living in a dormitory. Even if Brian is a college student and lives in a dormitory, that does not in any way guarantee the conclusion that all college students live in dormitories.

In general, inductive reasoning deals with probable truth, not guaranteed truth. Assuming that inductive reasoning has begun with true premises and followed acceptable principles, it has the property of **inductive strength.** An argument has inductive strength if it is improbable (but not impossible) for the premises to be true and the conclusion false (Skyrms, 1975).

In the next two sections, we will review examples of specific deductive and inductive reasoning tasks. These examples should help clarify the distinction between the two types of reasoning, which many argue call upon different modes of evaluation (Rips, 2001).

## Deductive Reasoning

Deductive reasoning has been of interest to psychologists, philosophers, and logicians since at least Aristotle (Adams, 1984). Various systems of logic were devised to set a standard to evaluate human reasoning. Although there are several kinds of deductive reasoning, we will examine only two: propositional and syllogistic reasoning. Before examining people's performance on these reasoning tasks, first we need to review the tasks themselves. To do so, let's briefly review some logical terms.

## Propositional Reasoning

**Propositional reasoning** involves drawing conclusions from premises that are in the form of propositions. A *proposition* can be thought of as an assertion—for example, "John likes chocolate cake," "The population of Northfield, Minnesota, is around 15,000," "Today is Friday." Propositions are either true or false. For the sake of convenience, they may be abbreviated to single letters—for example, letting $p$ stand for the proposition "Mary is a philosophy major."

Simple propositions, such as the ones just given, can be hooked together into more complicated (compound) propositions by using certain **logical connectives.** These connectives include & (ampersand), which functions somewhat as the English word *and* does (for example, "John likes chocolate cake, and Mary likes root beer"); $\vee$, which functions somewhat as the English word *or* does, only less so (for example, "George lives in Omaha, or my skirt is made of cotton"); $\neg$, the negation operator, akin to *not* (for example, "It is not true that the moon is made of green cheese"); and $\rightarrow$, called the material implication connective, which works roughly like the English construction "If . . . , then . . ." (for example, "If it is after five o'clock, then I should go home").

In these definitions, I said that each logical symbol functions somewhat as an English word does. What do I mean by this? Unlike English words, logical connectives are defined *truth-functionally*: The truth or falsity of a compound proposition such as $p$ & $q$ depends only on the truth or falsity of $p$ and the truth or falsity of $q$ (Suppes, 1957). Notice that truth functionality works differently from the way English is typically interpreted to work. Consider two sentences: "John got dressed, and John left the house" and "John left the house, and John got dressed." We tend to interpret these two sentences differently, seeing the first as a typical day in the life of John and the second as a possibly bizarre episode. However, if we let $p$ equal "John got dressed" and $q$ equal "John left the house," then "$p$ & $q$" has exactly the same interpretation in logic as "$q$ & $p$." We call these two compound propositions *logically equivalent*. The expression "$p$ & $q$" is given the truth value "true" if and only if $p$ is true and $q$ is true.

The connective $\vee$ matches up even less well with the English word *or*. The English term is typically used in the exclusive sense, as in "You can have a cookie or a candy bar" (implying that you can't have both). In contrast, $\vee$ is used in the inclusive sense. Thus a person who heard the previous statement and interpreted it in a strictly logical fashion could get more to eat than a person who interpreted the sentence in the typical way. The expression $p \vee q$ is true if and only if $p$ is true, $q$ is true, or both are true. Said another way, "$p \vee q$" is false if and only if $p$ is false and $q$ is false.

Next, let's consider the connective →. In logical terms, "$p \rightarrow q$" is equivalent (carries the same truth value) as "$\neg p \vee q$ (read: "not-*p* or *q*"). The equivalence is not at all intuitive but results from the way that ∨ is defined. We call *p* in the expression "$p \rightarrow q$" the antecedent, and *q* the consequent, and say that "$p \rightarrow q$" is true whenever the antecedent is false or the consequent is true. Alternatively, we could say that "$p \rightarrow q$" is false only when *p* is true and *q* is false. Thus the sentence "If my maternal grandmother lived to be 569 years old, then my car is a Mercedes-Benz" is automatically true (even though my only car is a Honda Odyssey), because the antecedent ("My maternal grandmother lived to be 569 years old") is false. Notice that in logic, no cause-and-effect relationship must be present, or is even implied. This contrasts with English, because we normally expect the antecedent (what precedes) to be related to the cause of the consequent (what follows) when we use the expression "If . . . , then. . . ." Also, when using the English expression, we consider "If *p*, then *q*" to be false if *p* is false and *q* true (unlike in logic, where it would be considered true).

Here's an example: I say, "If you don't stop practicing your tuba playing, I'll scream." In response, you cease your irritating playing. I scream anyway. I have behaved perfectly reasonably according to logic, even though I've violated your expectations. To see why, remember that the logical interpretation of "If *p*, then *q*" is equivalent to the logical interpretation of "not-*p* or *q*." Substituting for *p* and *q* with our example, then "If you don't stop practicing your tuba playing, (then) I'll scream" is the same thing (in logic) as "You [will] stop practicing your tuba playing [or] I'll scream [or both]."

Compound propositions can be formed out of simple propositions joined by connectives. Evaluating the truth status of such compound propositions can be a difficult task. The final truth values of any compound expression depend only on the truth values of the individual propositions. Logicians have often used truth tables as a systematic way to consider all possible combinations of truth values of individual propositions. In a **truth table,** every possible combination of truth values of individual propositions is listed, and the definitions of the connectives are used to fill in the overall truth value of the final expression. This method of solution is algorithmic, in the sense that it's guaranteed to reveal whether a compound proposition is always true (in which case it's called a **tautology**), sometimes true, or always false (in which case it's called a **contradiction**).

One big problem with truth tables, however, is that they grow at a very fast rate as the number of individual propositions increases. If there are *n* simple propositions in an expression, the truth table for that expression will be $2^n$ lines long. Various "shortcut" methods have therefore been developed, many of them in the form of rules of inference. Two well-known rules are *modus ponens* and *modus tollens.* Box 12-2 presents examples of valid rules of inference. To say that a rule is valid is to say that if the premises are true and the rules are followed, the conclusion will also be true.

### **Box 12-2** Examples of Inferences Rules and Fallacies

Symbols above the lines are premises; symbols below the lines are conclusions.

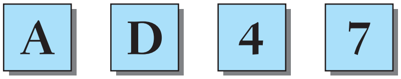
| *Modus Ponens (valid)* | *Modus Tollens (valid)* | *Denying the Antecedent (fallacy)* | *Affirming the Consequent (fallacy)* |
|---|---|---|---|
| $p \rightarrow q$ | $p \rightarrow q$ | $p \rightarrow q$ | $p \rightarrow q$ |
| $\underline{p}$ | $\underline{\neg q}$ | $\underline{\neg p}$ | $\underline{q}$ |
| $q$ | $\neg p$ | $\neg q$ | $p$ |

Also shown in Box 12-2 are two other "rules" that turn out not to be valid; that is, they can produce conclusions that are false even if the premises are true. "Rules" of this sort are called **fallacies.** Let's work through examples of why these rules are fallacies. Consider *affirming the consequent* as it applies to the following example: "If a man wears a tie, then he's a Republican. John is a Republican. Therefore, he wears a tie." Notice that the first premise ("If a man wears a tie, then he's a Republican") is *not* equivalent to the converse ("If a man is a Republican, then he wears a tie"). In fact, the first premise allows for the possibility of T-shirt-clad Republicans, which contradicts the conclusion.

The second fallacy, *denying the antecedent,* is exemplified in the argument "$p \rightarrow q$; $\neg p$, therefore $\neg q$." Using the example, these propositions would be instantiated as "If a man wears a tie, then he's a Republican. John does not wear a tie. Therefore, he is not a Republican." For the reason just given (namely, the possible existence of T-shirt-wearing Republicans), this argument is also false.

Now that we have discussed the nature of propositional reasoning, it is time to examine psychological investigations of how people actually perform on such tasks. Wason (1968, 1969, 1983; Wason & Johnson-Laird, 1970) studied people's propositional reasoning in a task he invented called the selection task, or the four-card task. Figure 12-1 presents an example. Participants see four cards, two with a letter and two with a digit. They are told that all four cards have a letter on one side and a digit on the other. They are given a rule such as "If a card has a vowel on one side, then it has an even number on the other side." We can restate this rule in propositional terms by letting $p$ equal "A card has a vowel on one side" and $q$ equal "A card has an even number on the other side." Then the rule can be written as "$p \rightarrow q$." The four cards presented to

**FIGURE 12-1** ■ *Depiction of the Wason (1968) selection task.*



participants might be something like "A" (exemplifying $p$), "D" (exemplifying $\neg p$), "4" (exemplifying $q$), and "7" (exemplifying $\neg q$). The person is asked to turn over all the cards, and only those cards, that would allow her to see if the rule is true. Before reading on, write down the one or more cards you would turn over. Also write down the reasons for your selections.

This is a task on which people make many errors. The correct answer is to select "A" and "7." To see why, refer to Box 12-2. Card "A" is relevant because, together with the rule ("If a card has a vowel on one side, then it has an even number on the other side"), it forms an instance of *modus ponens:* "$p \rightarrow q$, and $p$." Card "7" is similarly relevant because, together with the rule, it forms an instance of *modus tollens.* The "D" card is irrelevant because it exemplifies $\neg p$ and thus is an instance of denying the antecedent. And choosing the "4" card is equivalent to committing the fallacy of affirming the consequent. Generally, most people know to select "A" but neglect to select "7" or mistakenly select "4." We will discuss some general explanations for this pattern of performance later.

The puzzle given in Box 12-1 is also an instance of propositional reasoning. This puzzle is an example of a class of puzzles often called "truar/liar" or "knight/knave" puzzles, where the task is to determine which speakers are telling the truth and which are lying, assuming that every speaker is either a truar (knight) or a liar (knave) and that truars always tell the truth and liars always lie (Rips, 1989). Once again, we can translate the "stolen jam" story into propositions, letting $p$ stand for "The March Hare is telling the truth," $q$ stand for "The Mad Hatter is telling the truth," and $r$ stand for "The Dormouse is telling the truth." (Notice then that $\neg p$ would be "The March Hare is *not* telling the truth," and so on.)

## Syllogistic Reasoning

Another type of puzzle or problem commonly used to study reasoning is called a *syllogism.* The reasoning done with this kind of problem is called **syllogistic reasoning.** This type of problem presents two or more premises and asks the reasoner either to draw a conclusion or to evaluate a conclusion that the problem supplies, to see if the conclusion must be true whenever the premises are true. Although logicians recognize different types of syllogisms, we'll deal only with what are called *categorical syllogisms.* Box 12-3 presents some examples. As you look at these, try to solve them, making notes on which ones are hard, which ones are easy, and why.

Categorical syllogisms present premises that deal with classes of entities. As a result, the premises have words called *quantifiers* in them. Quantifiers provide information about how many members of a class are under consideration: all, none, or some. All the following are examples of quantified premises: "All Gordon setters are dogs," "No polar bears are inanimate objects," "Some flowers are blue," and "Some ballerinas are not tall." As you might expect by

### **Box 12-3** Examples of Categorical Syllogisms

Premises are above the lines; valid conclusions, if they exist, are below the lines.

All red books are astronomy books.
All astronomy books are large.
All red books are large.

Some pilots are magicians.
All magicians are Pisces.
Some pilots are Pisces.

No liberals are Republicans.
Some wealthy people are not Republicans.
Nothing follows.

Some documents are not paper.
Some documents are not legal.
Nothing follows.

All psychology majors are curious.
No tennis players are curious.
No tennis players are psychology majors.

No union members are fearful.
No children are fearful.
Nothing follows.

now, the words *all* and *some* are being used in ways that differ slightly from normal English usage. Here, *all* means “every single”; *some* means “at least one, and perhaps all.” (It is important to note that, logically speaking, the proposition “Some X are Y” does not mean that “Some X are not Y,” even though this inference might seem natural.)

Certain rules can be used to draw valid conclusions from categorical syllogisms (Damer, 1980). For example, a categorical syllogism with two negative premises (such as “No X are Y” or “Some X are not Y”) has no conclusion that necessarily follows. Similarly, a categorical syllogism in which both premises are quantified by “some” has no valid conclusion. In fact, the majority of categorical syllogisms do not have valid (always true in every case) conclusions.

With practice, people seem to develop their own “shortcut rules” for solving syllogisms. A research participant in a syllogistic reasoning study articulated such a rule after working on several syllogisms: “I thought about it a lot . . . and I realized that, when there’s a *some* and a *some*, nothing ever follows” (Galotti, Baron, & Sabini, 1986, p. 19). Performance on many categorical syllogisms is error-prone (Ceraso & Provitera, 1971; Woodworth & Sells, 1935). In general, people tend to be slower and make more errors when one or more premises are quantified by *some* or when one or more premises are negative. So, for example, when presented with syllogisms such as “Some businessmen are Republicans. Some Republicans are conservative,” most people erroneously conclude it must be true that “Some businessmen are conservative.” (To see why this is not the case, notice that the first premise allows for the possibility that some Republicans may exist who are not businessmen. Maybe they are all lawyers. Perhaps only these Republican lawyers are conservative.)

## Inductive Reasoning

Inductive reasoning, or reasoning about conclusions that are likely (but not guaranteed) to be true, probably occurs in everyone's thinking several times in the course of an ordinary day. Although inductive conclusions aren't guaranteed true, they may be more useful, because they actually add new information to our thinking. In general, it is easier to think of real-life examples of inductive reasoning than to think of real-life examples of deductive reasoning. Holyoak and Nisbett (1988) provided several examples of ordinary induction:

> A child who has never heard verbs rendered incorrectly into the past tense exclaims, "I goed to bed." A stock analyst, observing that for several years market prices for petroleum stocks have risen steadily in the final two months of the year and then dropped in January, urges her clients to buy petroleum stocks this year at the end of October and sell in late December. A physicist, observing the patterns formed by light as it undergoes refraction and diffraction, hypothesizes that light is propagated as waves. (p. 50)

Holyoak and Nisbett (1988) defined *induction* as "inferential processes that expand knowledge in the face of uncertainty" (p. 1). They noted that induction often involves categorization and the formation of rules or hypotheses. Thus you'll probably observe a great deal of overlap among induction, categorization (Chapter 8), and thinking (Chapter 11). There are a number of different inductive reasoning tasks, but I'll focus here on two: analogical reasoning and hypothesis testing.

### Analogical Reasoning

Figure 12-2 presents examples of both verbal and pictorial analogies. You may be familiar with this type of problem from standardized tests. The format of such a problem is "A is to B as C is to _____." The general idea is that the first two terms (A and B) suggest some relationship, and the third term (C) provides a partial description of another relationship. The job of the reasoner is to figure out what the fourth term (the one that goes in the blank) should be such that its relationship to the third term is the same (or nearly so) as the relationship between the first and the second terms.

Analogies can also be extended into what are called *series completion* and *matrix completion* problems. Figure 12-3 gives an example. Although these problems include more terms, the same general mental processes used in analogies are probably used to solve them (Sternberg & Gardner, 1983).

The ease of reasoning about an analogy depends on the complexity of the problem. Complexity, in turn, depends on a number of things, among them the following: How complicated to comprehend are the individual terms? How knowledgeable is the reasoner about the terms? How easy is it to find a

**FIGURE 12-2** ■ *Examples of verbal and pictorial analogies.*

Dog : Cocker Spaniel : : Cat :

(A) Sennenhund (B) Persian (C) Arabian

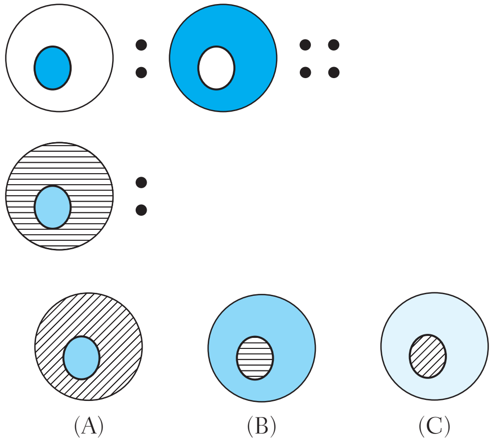
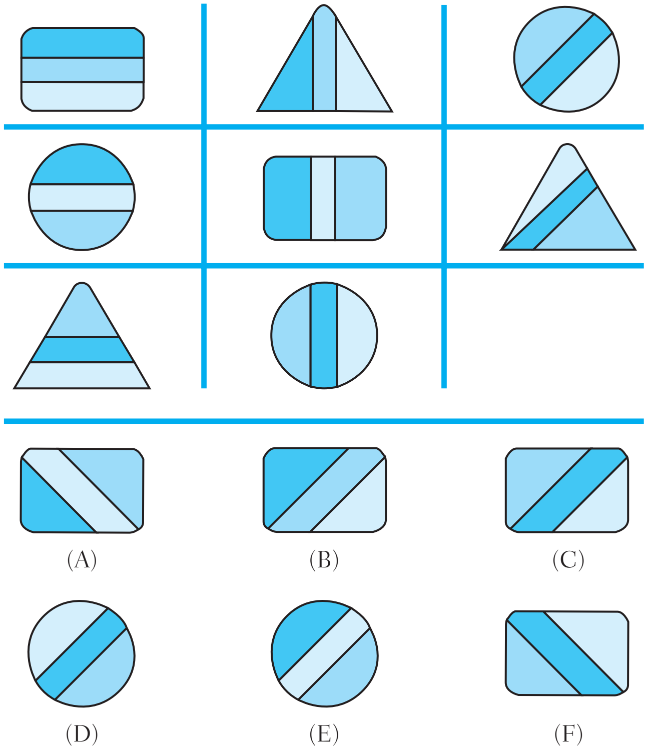


**FIGURE 12-3** ■ *Example of a matrix completion problem.*



relationship between the first two terms? How many possibilities are there for the blank term, and how easy are they to call to mind? (Pellegrino & Glaser, 1980; Sternberg, 1977a).

You have probably noted here a specific link to a topic we covered in Chapter 11—namely, reasoning by analogy as a problem-solving technique. Analogical reasoning is so common in our experience that we may use it in all sorts of tasks. Just as we try to find relations between terms in an analogy problem, so we try to find relationships between apparently dissimilar problems (for example, between the tumor problem and the problem of the general in the last chapter). In both cases, we try to apply the relationship found to determine the solution.

### Hypothesis Testing

Another example of inductive reasoning was also developed by Peter Wason (1960, 1977). The task is as follows: You are given the numbers 2, 4, and 6 and are told that this triplet of numbers follows a rule. Your job is to determine what the rule is, but to do so you need to observe certain guidelines. You may not ask direct questions about the rule. Instead, you have to offer your own examples of triplets, and for each one you give, you'll be told whether it follows the rule. Also, you should try not to guess; you should announce a rule only when you are confident you know what it is.

Of the 29 original participants, only 6 discovered the correct rule without first making incorrect guesses. Thirteen others made one wrong guess, 9 reached two or more incorrect conclusions, and 1 reached no conclusion at all (Wason, 1960). These results suggest, first of all, that this task is deceptively difficult. The manner in which most people go wrong seems to be as follows: They develop a general idea of the rule, then construct examples that follow the rule. What they fail to do is to test their rule by constructing a counterexample—a triplet that, if their rule is correct, *won't* receive a yes answer from the experimenter. Wason called this approach **confirmation bias,** because the participants seem to be trying to confirm that their rule is true, rather than trying to test their rule.

To explain why this approach is problematic, Wason pointed out a feature of the task that mirrors the situation facing any scientist testing other scientific hypotheses: An infinite number of hypotheses can be constructed consistent with any set of data (in this case, the triplets judged by the experimenter to follow the rule). For instance, suppose at a certain point in the experiment, you've found out that all the following triplets follow the rule (whatever it is): 2, 4, 6; 8, 10, 12; 20, 22, 24; 100, 102, 104. What rules are consistent with this set?

Here are just a few: "Any three even numbers that increase by 2"; "Any three even numbers that increase by 2, but the last number is not greater than

500"; "Any three even numbers where the second is the arithmetic average of the first and third"; "Any three even numbers where the second is the arithmetic average of the first and third, but the last number is not greater than 500"; "Any three even numbers that increase"; "Any three increasing numbers"; "Any three numbers"; "Any three things." This list suggests it's very easy, with a little thought, to generate hundreds of rules for any given set of numbers.

This means that no rule can be "proven" true, just as no scientific hypothesis can be proven true. To see this latter point, pretend you are a scientist with a hypothesis that predicts certain experimental results. You think, "If my hypothesis is true [$p$], then I'll obtain this pattern of results [$q$]." You then run the experiment, and, as luck or nature would have it, you do in fact obtain that pattern of results. Can you, on the basis of your rule ($p \rightarrow q$) and your obtained pattern of results ($q$), conclude that your hypothesis is proven true ($p$)? No, because if you did you would be committing the fallacy of affirming the consequent.

There simply is no pattern of results (even from hundreds of experiments) that can prove a theory true, just as no rule about three numbers can be proven true, even by a large number of examples that apparently follow it. Instead, the best one can do is to try to disprove as many incorrect rules (or, if you are a scientist, as many alternative hypotheses) as possible. So if you think the correct rule is "any three increasing even numbers," you are better off testing the rule with a triplet that is a *counter*example to the rule (for example, 3, 5, 7). Why? If this triplet *follows* the rule, then you know immediately that your hypothesis is wrong. Suppose you instead generate another example of the rule (such as 14, 16, 18). If you're told it does follow the rule, you won't be able to use it to prove your hypothesis true (because no hypothesis can ever be proven true), and you haven't managed to rule anything out.

## Everyday Reasoning

All the reasoning tasks presented so far are typical of tasks that psychologists use in experiments or that teachers might use in classes. These kinds of tasks have been grouped together under the label **formal reasoning** (Galotti, 1989). Philosophers, psychologists, and educators assume that these kinds of tasks are at the heart of all kinds of reasoning, even the kind of reasoning we do in everyday life. Consider the following example of **everyday reasoning:** You're preparing dinner, and the recipe you are following calls for mozzarella cheese. You search your refrigerator but can't find any. You conclude that you don't have any mozzarella cheese and that you'll need to go to the grocery store.

We can analyze the inferences you drew as follows. The inference that you had no mozzarella cheese can be seen as an instance of deductive reasoning, more specifically as an instance of *modus tollens* (for example, "If I had mozzarella cheese, it would be in the refrigerator. There is no mozzarella cheese in the refrigerator. Therefore, I have no mozzarella cheese"). Your inference that you need to go to the grocery store can be seen as an inductive inference (for example, "The grocery store usually stocks mozzarella cheese. Therefore, it will have mozzarella cheese in stock today"). These analyses assume that the mental processes you use in making inferences about mozzarella cheese are the same ones you would use in laboratory investigations of reasoning, such as knight/knave, categorical syllogism, or pictorial analogies tasks. The mozzarella cheese example is a more familiar variant of some of these tasks.

There is some reason to question, however, how similar the reasoning we use in everyday life is to the reasoning we use in laboratory tasks (Galotti & Komatsu, 1993). Collins and Michalski (1989) have identified certain kinds of inferences that people draw in everyday reasoning that do not seem to occur on formal reasoning tasks. For example, two people (identified as Q, the questioner, and R, the respondent) are having the following dialogue about geography (Collins & Michalski, 1989, p. 4):

> Q: Is Uruguay in the Andes Mountains?
>
> R: I get mixed up on a lot of South American countries (pause). I'm not even sure. I forget where Uruguay is in South America. It's a good guess to say that it's in the Andes Mountains because a lot of the countries are.

In this example, the respondent first expresses doubt, then draws an (incorrect, as it turns out) inference: Because many South American countries include a part of the Andes range within their territories, and because Uruguay is a typical South American country, the respondent concludes that it, too, includes some of the Andes Mountains. Collins and Michalski labeled this as a kind of "plausible deduction" (in our terminology, we might better call it a plausible induction, because the conclusion is not guaranteed to be true).

A number of distinctions between everyday reasoning tasks and formal reasoning tasks have been suggested (see Table 12-1). The differences may require cognitive psychologists studying reasoning to reevaluate the usefulness of laboratory reasoning tasks as a model of real-life reasoning performance. Research on people's everyday reasoning is beginning, and we will need to await more findings before assessing the fit between everyday and formal reasoning.

**Table 12-1** Formal and Everyday Reasoning Tasks Compared

| *Formal* | *Everyday* |
|---|---|
| All premises are supplied. | Some premises are implicit, and some are not supplied at all. |
| Problems are self-contained. | Problems are not self-contained. |
| Typically there is one correct answer. | Typically there are several possible answers, which vary in quality. |
| Established methods of inference that apply to the problem often exist. | Established procedures for solving the problem rarely exist. |
| It is typically unambiguous when the problem is solved. | It is often unclear whether the current "best" solution is good enough. |
| The content of the problem is often of limited, academic interest. | The content of the problem typically has potential personal relevance. |
| Problems are solved for their own sake. | Problems are often solved as a means of achieving other goals. |

**Source:** Galotti (1989, p. 335).

## PATTERNS OF REASONING PERFORMANCE

We have just reviewed examples of different reasoning tasks. We have seen that all of them can be quite demanding and that people who are untrained in logic often struggle with them. We have also seen that people can draw erroneous conclusions and be quite confident about them (even though they are wrong!). In this section, we will look at some patterns of performance across these different reasoning tasks, trying to identify some reasons why people's reasoning can sometimes go astray. We will also review explanations that psychologists have offered for the mental processes people use in reasoning.

### Effects of Premise Phrasing

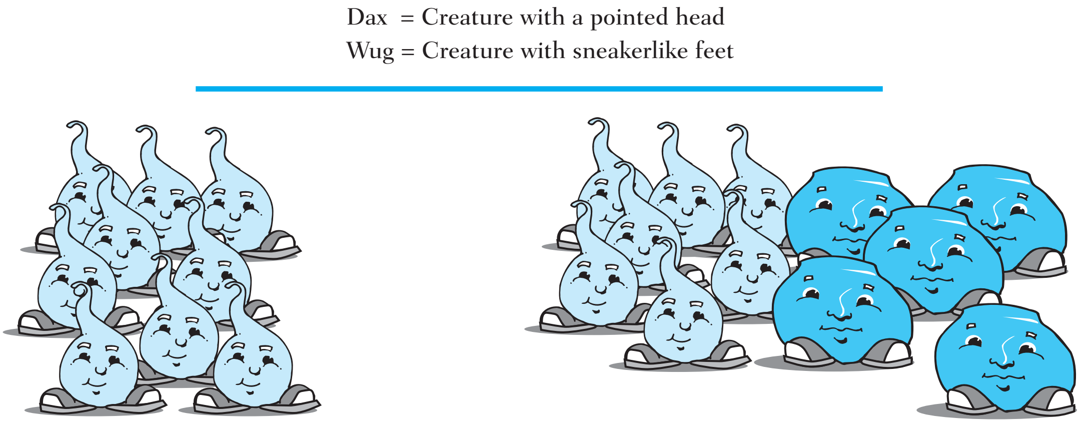
One general source of difficulty in reasoning, many psychologists assert, lies in the way premises are phrased. Premises that have negatives (the word *no* or *not* in them) are generally more difficult to work with, result in more errors, and take people longer to comprehend than premises that don't have negatives in them (Evans, 1972). Similarly, quantifiers such as *all* or *none* are easier for most people to deal with than quantifiers such as *some* (Neimark & Chapman, 1975). In addition, the order in which information is presented can be important. A syllogism presented in the order A-B, B-C (for example, “Some red books are astronomy books. All astronomy books are large.”) is much easier to work with than one presented in the order A-B, C-B (e.g., “Some red books are astronomy books. Some large books are astronomy books.”) or B-A, C-B (Johnson-Laird, 1975; Johnson-Laird & Bara, 1984; Johnson-Laird & Steedman, 1978).

More generally, it appears that the way information is stated can make a reasoning task easy or hard. Presumably, part of the explanation is that syntactically complex statements require more processing resources for the reasoner to comprehend, encode, represent, and store in working memory. As a result, there are fewer mental resources available to tackle other reasoning processes necessary to draw conclusions or to check for validity.

## Alteration of Premise Meaning

A second general finding is that people often misinterpret premises (despite the efforts of experimenters to get them to do otherwise). That is, people often make assumptions or alter the meanings of certain terms such that their interpretations of what the premises mean do not correspond very well with what the problem actually states. For example, when told “All daxes are wugs” (daxes and wugs being mythic amoebalike creatures), people often automatically assume that daxes and wugs are the same thing and/or that all wugs are daxes. In fact, the exact statement given allows two possibilities: Every dax is a wug, and every wug is a dax (the common interpretation), or every dax is a wug, and there are other wugs that are not daxes. Figure 12-4 provides an illustration.

**FIGURE 12-4** ■ *Illustration of possible meanings of “All daxes are wugs.”*

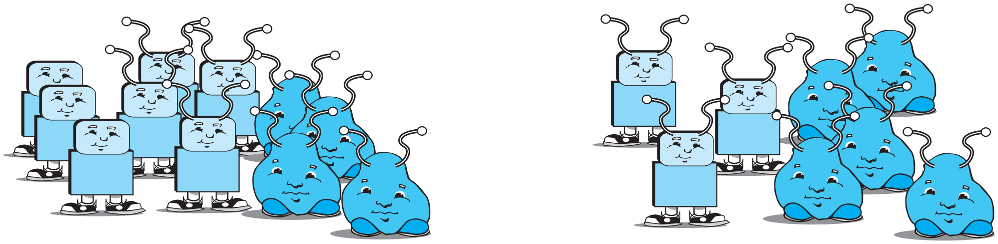

Dax = Creature with a pointed head
Wug = Creature with sneakerlike feet

All daxes are wugs.
(And all wugs are daxes.)

All daxes are wugs.
(And there are other wugs that aren’t daxes.)

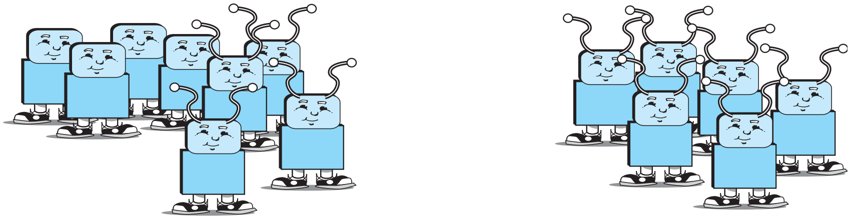
**FIGURE 12-5** ■ *Illustration of possible meanings of "Some bers are sabs."*

Ber = Creature with a square body
Sab = Creature with antennae



Some bers are sabs.
(And some bers aren't sabs.
And some sabs aren't bers.)

Some bers are sabs.
(And some sabs aren't bers.)



Some bers are sabs.
(And some bers aren't sabs.)

Some bers are sabs.
(In fact, all bers are sabs,
and all sabs are bers.)

The quantifier *some* in a premise compounds the difficulties. To say "Some bers are sabs" (bers and sabs are different amoebalike things) is to say only the following: "At least one ber is a sab, but there may or may not be other bers that aren't sabs, and there may or may not be other sabs that aren't bers." Figure 12-5 provides an illustration of all the possibilities. Generally, people wrongly interpret the statement as if it meant only the first possibility in Figure 12-5: that some bers are sabs and that some bers aren't sabs. People make a similar mistake with if–then statements. The statement "If A, then B" does not mean the same thing as "If B, then A," but this confusion is common. As in the case with *some,* people overlook possible interpretations of the premise.

It has been argued that many errors in drawing deductively valid conclusions can be traced to misinterpretations of premises (Revlis, 1975). Moreover, the problem persists even when people are given detailed definitions, as well as a fair amount of practice in applying these definitions (Galotti et al., 1986). Maybe the usual everyday understandings of words such as *all*, *some*, and *if–then* are so powerful that people have difficulty ignoring the fact that in reasoning tasks these terms are defined slightly differently.

## Failure to Consider All Possibilities

The preceding discussion implies that when people interpret premises, they often fail to think of all possible meanings. Similarly, when combining premise information, people often fail to think of many possibilities (Erickson, 1978).

Here's an example. Look again at Figure 12-5, which shows all the possible meanings of a premise quantified by *some*. Now, using Venn diagrams, draw all the possible combinations of the A, B, and C terms for the syllogism "Some A's are B's. Some B's are C's." Try to generate them all. When you think you have finished, look at Figure 12-6, which presents all the possibilities.

How many are in your drawing? A similar phenomenon is found with the Wason 2-4-6 task. People tend to think of only one (or very few) of the many possible rules that describe these triplets. As a consequence, the kinds of triplets they generate themselves are not as informative as they could be. If people realized the vast number of possible rules that could describe any set of triplets, they would probably test more of their own triplets before announcing a rule.

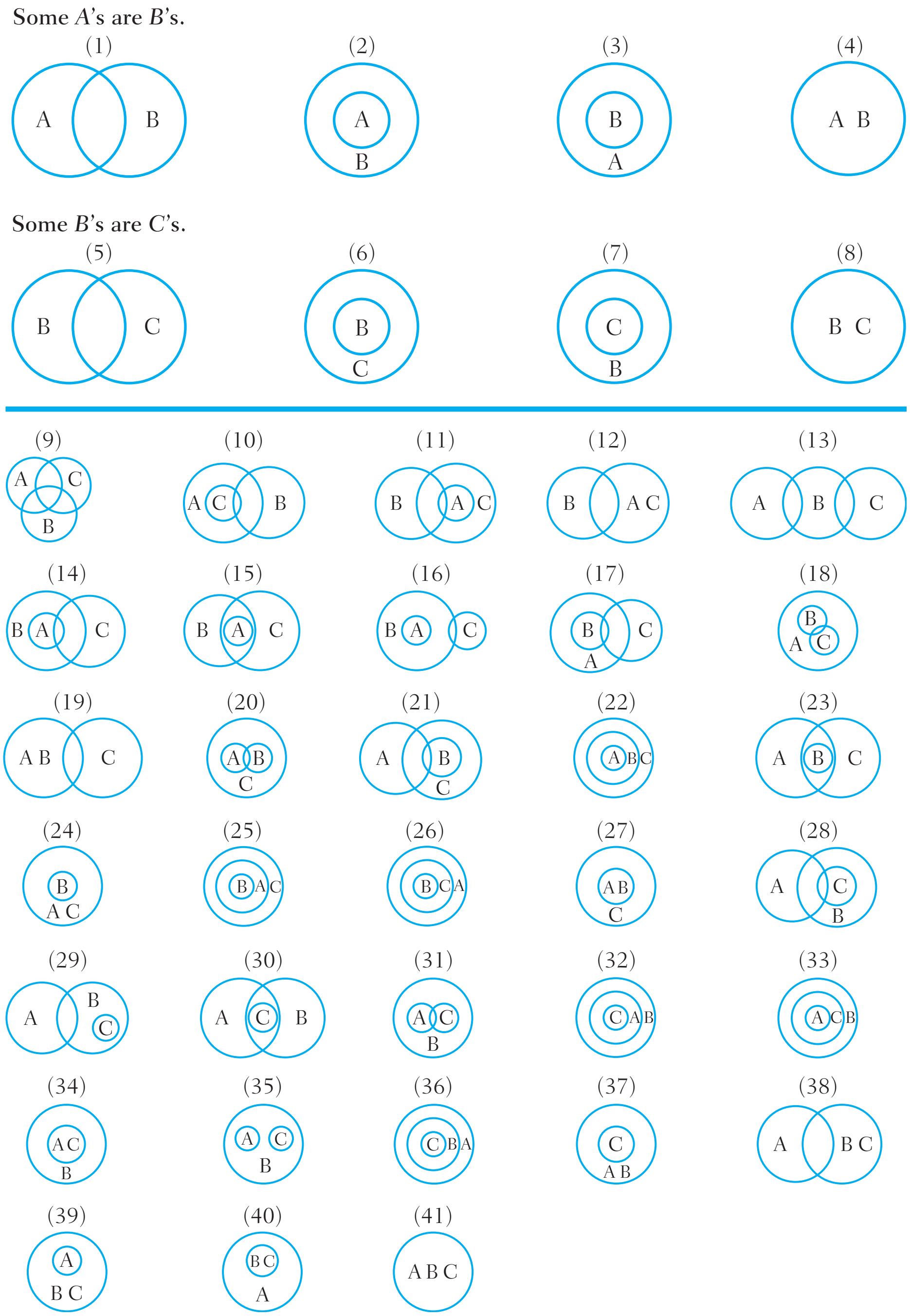
## Content and Believability Effects

Two people reasoning with exactly the same kind of premises will perform differently, depending on what the premises are "about." This is called a **content effect.** Recall the Wason four-card task, in which four cards are laid in front of you, labeled "A," "D," "4," and "7." Your task is to turn over all and only the cards that could test the rule "If a card has a vowel on one side, it has an even number on the other side." It turns out that performance improves dramatically if the four cards contain different information: on one side, a person's age; on the other, what the person is drinking. Then the four cards shown say "drinking a beer," "drinking a Coke," "16 years of age," and "22 years of age." The rule to be investigated is "If a person is drinking a beer, then the person must be over 19 years of age." This experiment was conducted by Griggs and Cox (1982, Experiment 3), who found that about three quarters of their college student participants solved the problem correctly when it was about drinking age but that none could solve the equivalent problem about letters and numbers.

What explains this effect? Griggs (1983) offered what he calls a "memory cueing" explanation. The idea is that certain contents of the problem cue, or call to mind, personal experiences that are relevant to the rule. College student participants in Griggs and Cox's (1982) experiment did well on the drinking-age version of the problem, it is argued, because their own experience with drinking-age laws (and perhaps with violations of those laws) let them think of what combinations of ages and beverages would violate the rule. The same participants had no comparable relevant experience to draw on when they reasoned about vowels and numbers in the other version of the task.

**FIGURE 12-6** ■ *Illustration of combinations of the premises "Some A's are B's" and "Some B's are C's."*

**SOURCE:** From Anderson (1980, p. 320).


Some A's are B's.
(1) A B
(2) A B
(3) B A
(4) A B
Some B's are C's.
(5) B C
(6) B C
(7) C B
(8) B C
(9) A C B
(10) A C B
(11) B A C
(12) B A C
(13) A B C
(14) B A C
(15) B A C
(16) B A C
(17) B A C
(18) B A C
(19) A B C
(20) A B C
(21) A B C
(22) A B C
(23) A B C
(24) B A C
(25) B A C
(26) B C A
(27) A B C
(28) A C B
(29) A B C
(30) A C B
(31) A C B
(32) C A B
(33) A C B
(34) A C B
(35) A C B
(36) C B A
(37) C A B
(38) A B C
(39) A B C
(40) B C A
(41) A B C

David Young-Wolff/PhotoEdit

*Griggs and Cox's (1982) work shows that people's reasoning about possible drinking age violations is far better than their performance on identically structured abstract reasoning tasks.*

Related to content effects are **believability effects.** People are likely to judge as valid any conclusion that reinforces their initial assumptions, regardless of whether the conclusion follows from the premises (Evans, Barston, & Pollard, 1983). Consider this syllogism: "Some college professors are intellectuals. Some intellectuals are liberals." The correct response to this syllogism (as you now know) is that no particular conclusion follows from it. Generally, though, most people (who haven't just read a chapter on reasoning) tend to conclude that these premises lead inevitably to the conclusion "Some college professors are liberals." This conclusion agrees with their previous beliefs and stereotypes about college professors: Professors are absentminded and theoretical, they are intelligent but sometimes impractical, they are unconcerned about money but are concerned about social justice. Notice that a change in this syllogism's content makes it much clearer why this conclusion isn't always true: "Some men are teachers. Some teachers are women." This syllogism calls to mind a different mental picture. Our world knowledge lets us filter out the suggested conclusion, "Some men are women," because we know this to be false in the world. You might also notice that this error could be described in terms of limited search within the problem space hypothesis, discussed in Chapter 11.

Recent work by Blanchette and Richards (2004) shows that simply changing the words in a conditional reasoning task from neutral words to emotional words (e.g., "If one is in a library, then one sees books" versus "If a person is being punished, then she will feel hurt") caused a decrease in reasoning performance. Given emotional content, people are likely to draw more invalid inferences than they are with neutral words.

### Biases

A **bias** in thinking is defined as a tendency to perform in a certain way regardless of the information presented. You might think of it as an error that frequently distorts thinking in a particular way. For example, a person might be biased toward coming to the most general conclusions possible and might then erroneously decide that broad generalizations necessarily follow from any set of premises.

Investigators have identified some biases relevant to reasoning. One, mentioned earlier with regard to the Wason 2-4-6 task, is confirmation bias—the tendency to look only for information that supports your existing beliefs. So, for example, if you believe that all college professors are liberal, you may try to "test" your conclusion but fail to do so adequately because you seek out only college professors who are liberal, somehow overlooking or forgetting about conservative college professors. In general, people have been shown to be much less likely to think of counterexamples to their own tentative conclusions (Baron, 1985, 2000). Thus, when assessing their own reasoning or other performance, people typically find it much easier to think of or gather information consistent with their predictions than to think of or gather information that goes against their predictions.

There are many other examples of biases in thinking, several of which are more relevant to decision making. We will therefore defer an extended discussion of biases in thinking to Chapter 13. The important point for our present purposes is to note that people often appear to exhibit thinking that is distorted in the direction of making it seem that their thinking or reasoning has been more careful or thorough than it actually has been.

## ■ THREE APPROACHES TO THE STUDY OF REASONING

So far, we've looked at a number of different reasoning tasks and offered several descriptions of the way people approach these tasks. In this section, I'll outline three major approaches to the study of reasoning—frameworks that attempt to explain a wide variety of reasoning, not just the reasoning that occurs on a specific task. I have labeled these strategies the *componential,* the *rules/heuristics,* and the *mental models* approaches (Galotti, 1989).

## The Componential Approach

The **componential approach** studies reasoning by analyzing a task into its component cognitive processes. A computer metaphor may be useful here. Those of you who have done computer programming know that programs can be built from subroutines, each of which performs a very specific function (such as sorting a list of numbers or adding a list of numbers). To understand how reasoning works, we need to figure out if analogous mental subroutines of reasoning exist and, if so, what they are, when and for how long each is executed, and the chances of each one's running without error.

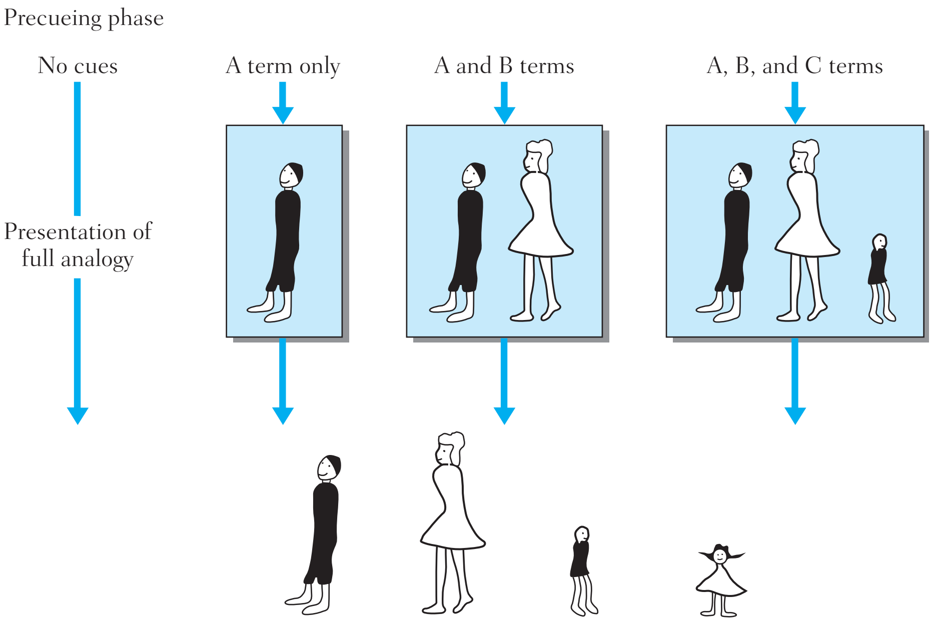
To illustrate, let's return to the sample analogy given at the beginning of the chapter: Washington is to one as Jefferson is to what? Sternberg (1977a, 1977b, 1986a, 1986b) studied people's performance on such problems extensively. He argued that to fill in the blank, we must perform several mental subroutines or, to put it more formally, execute a number of component cognitive processes. First we must encode each of the terms; that is, we must read the words *Washington, one,* and *Jefferson.* We then must recognize these terms, retrieving from memory the meaning of each term and mentally representing these meanings. Next we must infer the relationship between the first two terms (often called the A and the B terms)—in this case, *Washington* and *one.* One relationship that comes immediately to mind is that Washington was the first president of the United States. The next step is to map the A term and the C term (here, Jefferson)—that is, find a relationship between them. Jefferson was also a president of the United States. In the next step, we apply the relationship previously found between the A and the B terms onto the C term, remembering (if we recall our U.S. history) that Jefferson was the third president. Thus our answer to the analogy would be three.

Sometimes analogies are provided in multiple-choice format, and in those cases the answers don't always fit. Suppose the preceding analogy had been presented in this form: "Washington is to 1 as Jefferson is to (a) 2, (b) 10, or (c) 16." Which answer would you choose? It might take a bit of reorganizing and a look through your wallet (or a trip to your local Federal Reserve Bank), but after a while, the answers presented might cue you that the first relationship you thought of between Washington and one was not a good relationship for this problem. In that case, you might think of other possibilities. Washington is pictured on the one-dollar bill, for instance, and Jefferson on the two-dollar bill. Here answer (a) fits neatly. In the case where none of the provided answers fits perfectly, you might need to engage in a process of justification to provide reasons that the answer you choose, although imperfect, is better than the others.

In Sternberg's theory, each component has associated with it several parameters that determine, for instance, the probability that it will be used, the amount of time it will take to execute, and the difficulty of executing it. Sternberg's method of estimating these parameters was quite clever. He presented participants with a number of different verbal and pictorial analogies (Sternberg, 1977a) on a tachistoscope, and each trial consisted of two parts: (a) precueing and (b) presentation of the full analogy. Figure 12-7 presents examples.

**FIGURE 12-7** ■ *Examples of stimuli and experimental design.*

**SOURCE:** From Sternberg (1977a, p. 361).



During precueing, participants saw either a blank field (no cues), the A term of the analogy only, the A and the B terms of the analogy only, or the A, B, and C terms of the analogy. Sternberg (1977a) compared the amounts of time it took participants to decide if the full analogy was true or false on trials with no cues to the amounts of time on trials in which cues had first appeared. For example, when participants had been precued with the A term, Sternberg reasoned that they had been able to encode this term; thus they should be (and were) faster to respond to the full analogy. Let's say it took participants, on average, 2 seconds to respond to the full analogy, but only 1.8 seconds when the A term was precued. That 0.2-second difference presumably reflects the time it takes to encode the A term. Similarly, if participants were precued with the A and B terms and then took only 1 second to respond to the full analogy, we could infer that the other 1 second was the time it took to encode the A term, encode the B term, and infer a relationship between them.

Sternberg and his colleagues (Sternberg & Gardner, 1983; Sternberg & Turner, 1981) have studied other inductive reasoning tasks and have presented componential models of each. Each componential model identifies the mental processes (such as encoding or comparing) that are used in each task. From these studies, Sternberg has argued that the componential approach to the study of reasoning will reveal important insights into what reasoning is and how it can be improved (Sternberg, 1986a).

In later work, Sternberg (1983, 1984) distinguished among three kinds of components used in reasoning. Components that consist of individual cognitive processes are called *performance components* and include those given earlier. *Metacomponents* are "executive" processes used in the planning and monitoring of a task. For example, metacomponents select which performance components will be used and in what order. *Knowledge acquisition components* are used whenever we acquire new information. These include things such as selective encoding (sifting relevant from irrelevant information), selective combination of previously encoded information, and selective comparison.

Consider some concrete examples of each type of component. We have already seen examples of performance components, including such things as encoding (mentally representing stimuli), comparing, applying a rule, and so on, in the discussion of Sternberg's studies of analogies. Metacomponents have to do with planning and monitoring of performance. You use metacomponents when you are confronted with a reasoning task and you step back to think about how you would go about solving it. Any time you plan a strategy for a task or question your performance on that task ("Let's see. I should probably be on guard for confirmation bias. Is there any way I've overlooked evidence contrary to my beliefs?"), you are making use of metacomponents.

Knowledge acquisition components have to do with how we learn or pick up new information. Sternberg (1986a) argued that people differ in the ways in which they learn: Given the same exposure to the same novel situation, two people may acquire different kinds and amounts of information from it. The mental processes we use in learning are knowledge acquisition components.

Sternberg's (1986a) book gives advice and examples to provide practice with performance components, metacomponents, and knowledge acquisition components. Many errors in reasoning tasks appear to stem from problems in encoding (a performance component). Many of the problems in reasoning noted earlier (such as problems with premise interpretations, alteration of premise meanings, or failure to consider all possibilities) arise because reasoners fail to encode enough relevant information. Moreover, complicated syntactic expressions (those with many terms, those with negatives) presumably take more processing resources to encode, leaving fewer resources available for other components of reasoning. Other problems in reasoning could be described in terms of differences in using metacomponents. A reasoner who plans her approach to a problem ("Let's see. Before I start, let me be sure I understand what terms like *some* and *all* mean—the people who wrote the problem might mean something other than I do with these terms.") and monitors his or her performance ("OK, wait a minute. Have I checked to be sure I've covered all possibilities?") is less likely to be biased or to make other kinds of errors.

## The Rules/Heuristics Approach

Sternberg's componential approach treats reasoning as just another mental activity, similar in kind to tasks such as problem solving or making decisions. Other philosophers and psychologists have seen reasoning as a special mental process, one for which people rely on special-purpose mental rules to draw conclusions. That is, using the terminology of Chapter 10, they see reasoning as a modular process.

One idea is that the rules of logic are the same rules we use to draw conclusions (this position was articulated by the philosophers Kant and Mill; see Henle, 1971, for details). Most modern psychologists reject the strong version of this idea but agree that people use "mental logics" or systems of inference rules to draw conclusions (Braine, 1978, 1990; Braine, Reiser, & Rumain, 1984; Osherson, 1975; Rips, 1984, 1988, 1990). Using this **rules/heuristics approach,** these researchers make an analogy between mental logics and grammars: Both are systems of rules to which we have only implicit access. So you can't be expected to state all the rules you follow to draw conclusions—you may not even know you do follow rules! However, the researchers argue that if we carefully observe your behavior while you reason, we will find regularities in the way you draw conclusions that are most easily explained by assuming you have followed—probably without being conscious of doing so—a set of rules. (You might review our discussion in Chapter 10 of people's implicit awareness of grammatical rules to get a better idea of how this might work.)

Different researchers describe slightly different sets of inference rules. Generally, rules take the form "(premises) → (conclusion)." Here's a specific example (from Braine, 1978): "$p \vee q$; $\neg p$ therefore $q$." The idea is that when given information, people try to match it to one of these rules and use the rules to draw appropriate conclusions. Imagine being told, for instance, that either *ER* or *House* won an award for best television drama, and that *ER* did not win. You match this information to the rule just given and easily conclude that the victor must have been *House*. Braine considered the use of inference rules automatic and, typically, errorless.

These proposals are not the only ones that view reasoning in terms of mental rules. Work by philosophers on practical logic also follows a rules approach. The goal of practical logic is to teach people to avoid fallacies or errors that occur in real-life arguments. Box 12-4 presents some common fallacies. Rules for avoiding fallacies could take the form "If [this particular fallacy occurs], then the argument is not a good one." Thus the strategy of practical logic, as typically taught, is to compare real-world arguments with a list of fallacies. If no matches are found, and if the list is complete, the argument is considered a good one.

### Box 12-4 Examples of Fallacies in Reasoning

- *Equivocation.* Using a word in two ways, while appearing to use the same meaning throughout. Example: "Scientific authorities believe that smoking causes cancer, but I know a lot of scientists who don't even control their own kids very well, so what kind of authorities are they?"
- *Illicit contrast.* Leading a listener to draw an inappropriate inference by placing unusual emphasis on certain words or phrases. Example: "I'm glad I'm a Democrat. Democrats aren't crooks."
- *Argument by innuendo.* Directing the listener to a particular conclusion by a careful choice of words or arrangement of sentences. Example: "Is Jeff a good guy? Well, we've never caught him doing anything illegal."
- *Loaded question.* Using language that presupposes a certain conclusion. Example: "When are you going to stop cheating on your income taxes?"
- *Fallacy of the continuum.* Assuming that small differences are always unimportant. Example: "I know that our monthly payments are already very high, but what's another $40 a month?"
- *Fallacy of composition.* Assuming that what is true of the parts is true of the whole. Example: "Anna has a good head on her shoulders, and Scott's good with people, so their success as business partners is guaranteed."

**SOURCE:** After Damer (1980); his book describes many other fallacies and examples.

The key issue for the rules explanation of reasoning is how people figure out when and what rules apply. Braine (1990) proposed the existence of abstract rules that we use in all situations. Patricia Cheng and her colleagues (Cheng & Holyoak, 1985; Cheng, Holyoak, Nisbett, & Oliver, 1986; Nisbett, Fong, Lehman, & Cheng, 1987) rejected the idea of abstract rules, instead proposing sets of rules that are sensitive to the context. The idea here is that different rules are called to mind in different situations.

One example is the permission schema, made up of four rules:

Rule 1. If the action is to be taken, then the precondition must be satisfied.

Rule 2. If the action is not to be taken, then the precondition need not be satisfied.

Rule 3. If the precondition is satisfied, then the action may be taken.

Rule 4. If the precondition is not satisfied, then the action must not be taken.

The permission schema would be activated in certain contexts but not others. For instance, the problem "One may consume alcoholic beverages only if born before June 3, 1986. Beth's birthday is July 31, 1996. May Beth drink a beer?" would evoke the permission schema. Presumably, people's familiarity with age restrictions on drinking helps them construe the problem in terms of permission: Does Beth, given her age, have legal permission to consume an alcoholic beverage? A problem similar in abstract form—"All employees use Midnight Airlines whenever they travel to New England. Sara, an executive, is flying to San Francisco. Will Sara necessarily fly Midnight?"—would not necessarily evoke the permission schema because nothing in the problem makes the reasoner construe it as a problem about permission.

Notice the difference between the proposals of Braine (1990) and Cheng (Cheng et al., 1986). Cheng's idea is that in reasoning, people interpret problems in terms of what they are about (for example, drinking) and, on the basis of this analysis, use different schemata. In her view, two problems that have the same abstract logical structure (that is, can be expressed the same way symbolically) may be treated very differently, depending on how people interpret the problems. Braine, instead, argued that people can and do use the same set of abstract rules in all situations.

Leda Cosmides and her colleagues (Cosmides, 1989; Cosmides & Tooby, 2002; Fiddick, Cosmides, & Tooby, 2000) offer an evolutionary account of reasoning rules. Her argument is based on the idea that people (as well as all other organisms) have been shaped by evolutionary forces.

> Even if they have not paid much attention to the fact, cognitive psychologists have always known that the human mind is not merely a computational system with the design features of a modern computer, but a biological system "designed" by the organizing forces of evolution. This means that the innate information-processing mechanisms that comprise the human mind were not designed to solve arbitrary tasks, but are, instead, adaptations: mechanisms designed to solve the specific biological problems posed by the physical, ecological, and social environments encountered by our ancestors during the course of human evolution. However, most cognitive psychologists are not fully aware of just how useful these simple facts can be in the experimental investigation of human information-processing mechanisms. (Cosmides, 1989, p. 188)

Cosmides goes on to argue that much of cognition is not supported by domain-general or independent mechanisms, rules, or algorithms, but instead by many, very specific mechanisms, adapted evolutionarily to solve very specific problems. For example, she believes that evolution has pressured humans to become very adept at reasoning about social contracts and social exchange.

> Social exchange—cooperation between two or more individuals for mutual benefit—is biologically rare: few of the many species on earth have evolved the specialized capacities necessary to engage in it. . . . Humans, however, are one of these species, and social exchange is a pervasive aspect of all human cultures.
>
> The ecological and life-historical conditions necessary for the evolution of social exchange were manifest during hominid evolution. Pleistocene small group living and the advantages of cooperation in hunting and gathering afforded many opportunities for individuals to increase their fitness through the exchange of goods, services, and privileges over the course of a lifetime. (1989, pp. 195–196)

Cosmides (1989) asserts that any evolutionarily adaptive mechanism for reasoning about social exchange must fulfill two criteria: (a) It must concern itself with costs and benefits of social exchanges, and (b) it must be able to detect cheating in social exchanges. A person who was not able to think in terms of costs and benefits would not be able to reason successfully about the worthiness of a proposed social exchange, and a person unable to detect cheating would presumably be at a big disadvantage in any society.

Cosmides (1989) predicted that people would be especially adept at the Wason selection task when the content of the task could be construed in terms of social costs and benefits. So, she reasoned, people do well on the underage drinking version of the task because this version causes people to invoke their special-purpose reasoning mechanism about social exchange. The drinking problem version of the Wason selection task asks reasoners to look for violations (cheating) of a social contract: that only those who have attained legal majority (thus paying a kind of "cost") are authorized to partake of a "benefit" (consuming alcoholic beverages). Reviewing the literature on content effects in reasoning, Cosmides concluded that unless the content had an implicit or explicit cost–benefit structure, people's reasoning was not enhanced.

We saw earlier that the componential approach locates the source of errors in reasoning in people's inability to use certain performance components or metacomponents effectively. The rules approach to reasoning offers a different interpretation: A common source of error in reasoning is the failure to interpret a problem in terms of the appropriate rules—in other words, a failure to see which rules are relevant in a particular instance. People may fail to make any mental match to an appropriate rule or may use inference rules that do not apply to a given situation. It may also be that inference rules do not exist for many kinds of reasoning; in such cases, people are assumed to use some other kinds of strategies, and these may be prone to error.

The rules approach to reasoning is particularly effective at explaining content effects in reasoning, as we have seen. The explanation goes as follows: Presumably, different contents "cue" different sets of rules, although exactly how this process works is not well understood. It may be that personal experience facilitates this cueing, so that people are more likely to reason correctly with premises about drinking ages simply because their own experiences cause them to interpret the situation in terms of a permission rule.

Cheng et al. (1986) have reported success in teaching people to recognize and use pragmatic reasoning rules correctly after only brief periods of practice. This suggests that people quickly learn to use inference rules as a guide to processing information on certain tasks. Similarly, the existence of logic courses in colleges and universities suggests that rules of logic can be taught. The hope is, of course, that people who learn to use a set of inference rules in one situation will transfer their understanding of the rules to new circumstances.

## The Mental Models Approach

Proponents of the **mental models approach** deny that reasoning consists of using special-purpose rules of inference and that reasoning involves special-purpose cognitive processes. Philip Johnson-Laird (1982, 1983), a major spokesperson for the models approach, argued that the processes we use to draw conclusions are also the ones we use to comprehend language.

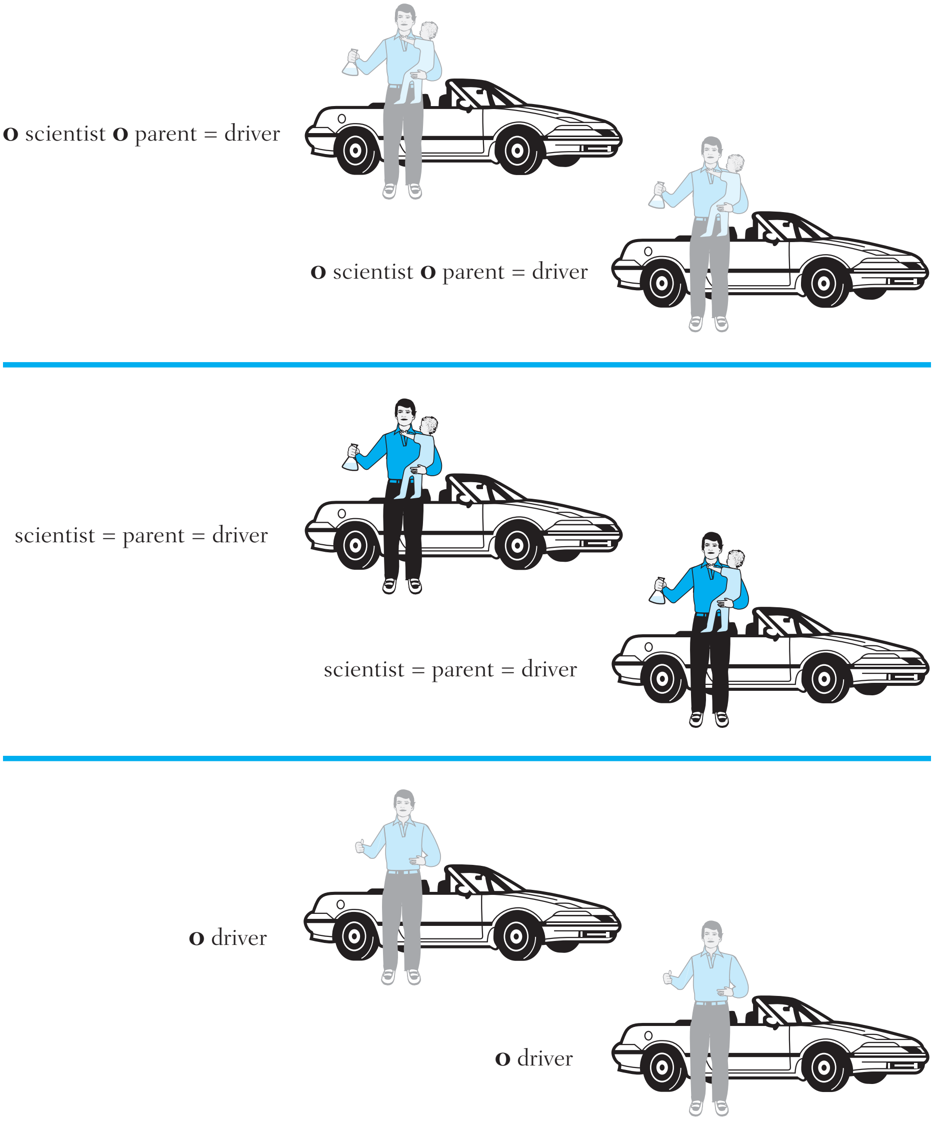
Reasoning, for Johnson-Laird, consists of constructing mental models to depict the premises. Effective reasoning occurs when the reasoner checks to be sure his or her first idea of what the conclusion might be is assessed by an attempt to construct alternative models consistent with the premises but inconsistent with the hypothesized conclusion.

To explore Johnson-Laird's approach, consider the following syllogism: "Some of the scientists are parents. All of the parents are drivers." Figure 12-8 offers one interpretation of how these premises might be mentally modeled for this relatively easy-to-solve reasoning problem. Scientists are depicted as people holding a flask; drivers, as people standing next to a car; and parents, as people holding a child. The diagram indicates that some scientists are drivers but (possibly) some other scientists aren't drivers (those shown in faded lines) and, also possibly, some drivers aren't parents (also rendered in faded lines). Notice that the two scientists in the middle of the diagram (the ones who aren't "optional") are drivers, leading to the necessarily true conclusion, "Some of the scientists are drivers."

**FIGURE 12-8** ■ *Model representation of an easy categorical syllogism.*

**SOURCE:** Oakhill, Johnson-Laird, and Garnham (1989).

The **o** before the elements indicates optional individuals who may or may not be present.


o scientist o parent = driver
o scientist o parent = driver
scientist = parent = driver
scientist = parent = driver
o driver
o driver

Syllogism depicted: Some of the scientists are parents. All of the parents are drivers.

How do people construct these mental models? The fact that people understand stories or conversations, Johnson-Laird argued, makes them expert constructors of mental models. Whenever we read a story, for instance, we build some sort of mental picture of the text in order to comprehend it. Similar mental processes occur when we take part in or even observe a conversation.

These processes are also the ones we use when we encode a premise such as “Some of the scientists are parents.” What, then, distinguishes language comprehension from reasoning? In the case of language comprehension, we usually stop constructing models once we construct one that both represents the essential information and makes sense. Reasoning requires one more thing: the ability and willingness to try to construct alternative models that represent all the possibilities.

Consider another of Johnson-Laird’s syllogisms, this one more difficult to work with: “All of the beekeepers are artists. None of the chemists are beekeepers.” You might try this one yourself before reading on. Figure 12-9(A) depicts the model most people generate first. Notice that no individual is both a chemist and a beekeeper nor both a chemist and an artist. This depiction would lead one to conclude, “None of the chemists are artists.” However, if they keep at it, people may discover other possible depictions, such as the one shown in Figure 12-9(B), where one artist is a chemist. This depiction means the preceding conclusion cannot be true. At this point, a reasoner who had constructed both models might conclude, “Some of the chemists are not artists.” Again, however, another possibility exists, the one depicted in Figure 12-9(C). Here, all the chemists are artists, so the last conclusion cannot be valid, either. Is there no valid conclusion, then? In fact, there is. The one statement true of all three models is “Some of the artists are not chemists.” In particular, the beekeeper/artists, necessarily depicted in each model, are not chemists.

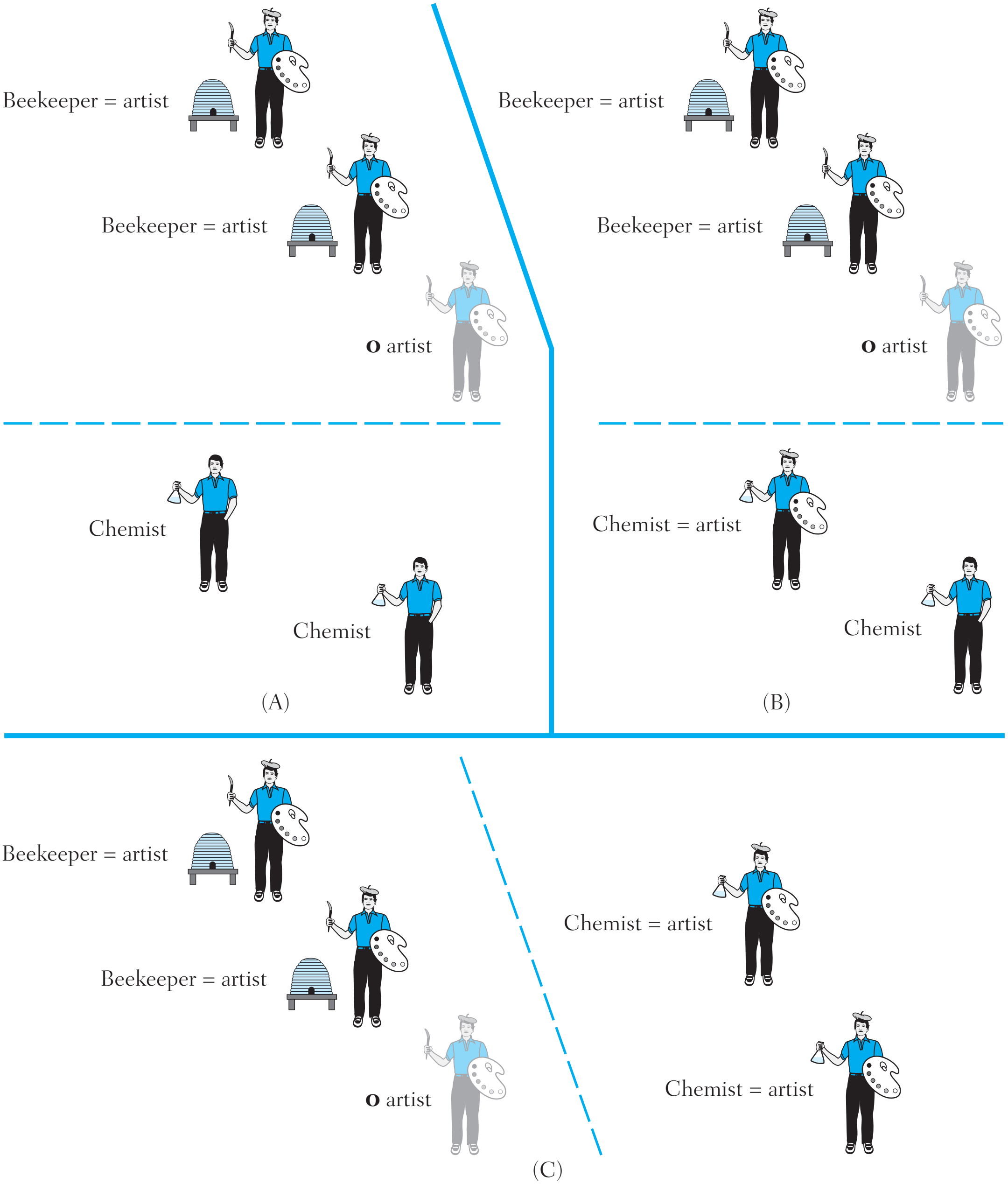
One problem with the mental models framework is specifying what information models contain and what information is omitted. Notice, for instance, that in Figures 12-8 and 12-9 we did not specify any physical, ethnic, or philosophical information about the people depicted. How much information the reasoner chooses to represent and how this decision affects performance are issues that remain to be investigated.

The construction of a mental model can be considered a creative act. Perkins (1985) argued that—contrary to stereotype—model building (and therefore good reasoning) relies on imagination. The more imaginative the process, the more likely a reasoner is to generate potential counterexamples and avoid drawing hasty conclusions. Interestingly, this view links reasoning with other kinds of thinking, helping to explain the apparent links among reasoning, problem solving, and decision making.

In the mental models approach, errors in reasoning derive from several possible sources. One is the failure to construct relevant models. If the premises are

**FIGURE 12-9** ■ *Model representation of a harder categorical syllogism.*

**SOURCE:** Oakhill et al. (1989).


Beekeeper = artist
Beekeeper = artist
o artist
Chemist
Chemist
(A)
Beekeeper = artist
Beekeeper = artist
o artist
Chemist = artist
Chemist
(B)
Beekeeper = artist
Beekeeper = artist
o artist
Chemist = artist
Chemist = artist
(C)

The **o** before the elements indicates optional individuals who may or may not be present.

Syllogism depicted: All of the beekeepers are artists. None of the chemists are beekeepers.

not presented in an optimal order (for example, in a syllogism, in the order A-B, B-C), it is harder to construct an integrated representation of both premises that accurately depicts all the relevant information. If there is a great deal of extraneous information in the premises, mental resources may be diverted from the processes needed to selectively represent the essential information.

A second source of error is the failure to assess the implications of all the models found. For instance, in the previous example, someone might have decided that no conclusion relating artists and chemists was valid, overlooking the one relation shown in all three models. A final and important source of error is the failure to search for and construct enough models. This accounts for the findings described earlier—namely, that people often fail to consider enough of the possibilities allowed by any set of premises.

Having now reviewed the three approaches to reasoning, you are probably trying to determine which one fits the data best. Table 12-2 compares the three and shows that each one has particular strengths and weaknesses. The three approaches also differ in the level of investigation toward which they are aimed. The componential approach seeks to explain the individual cognitive processes used in each episode of reasoning. The rules/heuristics approach focuses on a more general issue, the patterns involved in thinking. The mental models approach has a different goal, to explain reasoning performance at a general level of mental strategy. Each of these approaches is necessary if we are eventually to understand all the significant reasoning phenomena.

## ■ NEUROPSYCHOLOGICAL EVIDENCE ON REASONING

Some neuropsychological work has begun to try to distinguish between the rules and the mental models approaches to explaining reasoning performance. Vinod Goel and his colleagues (Goel, Buchel, Frith, & Dolan, 2000; Goel & Dolan, 2001; Goel, Gold, Kapur, & Houle, 1998) have conducted studies of adults performing various reasoning tasks, including categorical syllogisms and three-term series problems (for example, "Karen is in front of Larry. Larry is in front of Jane. Is Karen in front of Jane?"). Research participants worked on problems while undergoing an fMRI or PET scan.

These studies found that different areas of the brain are activated for different tasks, and depending on whether the premises are concrete, as in the Karen-Larry-Jane example, or abstract ("K is in front of L. L is in front of J. Is K in front of J?"). Goel and associates interpreted their results as being more in line with the mental models approach, as they found significant involvement of areas of the brain having to do with visual and spatial perception. However, much work remains to be done to assess the generality of these results across various reasoning tasks.

## Table 12-2 Comparing Three Approaches to Reasoning

| *Point of Comparison* | *Componential* | *Rules/Heuristics* | *Mental Models* |
|---|---|---|---|
| *Nature of the fundamental unit* | • Component (information-processing routine) | • Inference rule (rule) | • Mental model (representation) |
| *Definition of reasoning* | • Using one or more particular assemblies of component processes to encode, find, map, or apply a relationship | • Following (implicitly or explicitly) a rule, heuristic, or schema to make inferences | • Constructing one or more representations consistent with given information to reach and test conclusions |
| *Range of existing reasoning tasks applied to so far* | • Analogies; series completions; conditional, categorical, and linear syllogisms; mathematical and verbal induction; detective-story problems | • Conditional, categorical, and linear syllogisms; probabalistic and statistical reasoning problems | • Conditional, categorical, and linear syllogisms; open-ended reasoning about social and political issues |
| *Major findings easily explained* | • Difficulty with negative and marked premise terms; problems in encoding on formal reasoning tasks | • Content effects; intrusion of background knowledge | • Failure to consider all possible interpretations or consequences of premises; intrusion of background knowledge |
| *Other strengths* | • Great deal of empirical data that tests theory | • Good amount of empirical data that tests theory; has attracted investigators from several fields (philosophy, psychology, artificial intelligence, linguistics) | • Specifically designed to be extendable to everyday reasoning |
| *Major shortcomings* | • Lack of analysis of which components are used in everyday reasoning; lack of definition of the term *component* | • Lack of specificity over when and how rules are used; lack of definition of the term *rule* | • Lack of empirical data, especially training studies; lack of definition of the term *model* |

**Source:** Galotti (1989, p. 346).

Waltz and colleagues (1999) found that patients with prefrontal cortex damage were catastrophically hampered in their ability to reason with problems requiring the integration of multiple propositions (e.g., Beth is taller than Tina, Amy is taller than Beth) when the premises were not in a direct order permitting easy integration (Amy is taller than Beth, Beth is taller than Tina). Interestingly, patients with prefrontal cortex damage did not show deficits in their IQs or in their semantic memories. The deficit persisted on inductive reasoning tasks that required integration of different relations as well. The authors believe that the prefrontal cortex, shown to be important in many complex cognitive tasks, might be specialized for the integration of relations—that is, putting together different pieces of information into a unified mental representation.

## SUMMARY

1. Reasoning involves goal-directed thinking, drawing conclusions from other information. The inferences made may be automatic or intentional.
2. There are a variety of types of reasoning. Deductive reasoning involves conclusions that are logically necessary, or valid. Examples include propositional or syllogistic reasoning. Inductive reasoning can lead only to conclusions that possess some degree of inductive strength. Examples here include analogies and hypothesis testing.
3. Formal reasoning includes tasks in which all the premises are supplied and the problems are self-contained; they usually have one correct, unambiguous answer and often contain content of limited interest. Everyday reasoning tasks often involve implicit premises, are typically not self-contained, and are often of personal relevance.
4. Psychologists seek general principles of human reasoning, not limited to only one reasoning task. Some findings from the reasoning literature seem to hold true for a variety of reasoning tasks. For example, the way premises are phrased can greatly influence performance: People often misinterpret what premises mean or overlook possible interpretations of the premises' meanings. Reasoning is also subject to content and believability effects: People may perform very differently with different versions of the same problem, depending on the content of the problem.
5. Theoretical approaches to the study of reasoning vary and depend heavily on whether reasoning is considered a separate process from other kinds of mental activity. Those who consider reasoning to be very distinct focus on self-contained problems, often emphasizing special-purpose rules of inference as the mechanism for drawing conclusions. Others see reasoning as an extension of other aspects of mental life, such as language comprehension or thinking. In this view, the way to

understand reasoning is not to search for special-purpose cognitive processes or rules but to examine general aspects of mental performance—why people fail to consider enough of the relevant evidence or to imagine enough of the possibilities.

6. The prefrontal cortex has been implicated as playing a very important role in a person's ability to integrate relations—that is, to build a mental representation that incorporates multiple propositions or relationships.

## REVIEW QUESTIONS

1. Describe the similarities and differences between inductive and deductive reasoning.
2. Describe and contrast two methods by which people can derive conclusions in propositional reasoning tasks.
3. Distinguish between formal and everyday reasoning. How might the former be relevant to the latter?
4. *(Challenging)* Consider factors that hinder people's reasoning. In what ways are these factors present for other kinds of thinking and problem-solving tasks? (*Hint:* Review Chapter 11.) What does your answer imply about the relationship between thinking and reasoning?
5. Describe and give a new example of confirmation bias.
6. Describe the componential, rules/heuristics, and mental models approaches to studying reasoning. What are the differences and similarities among them?
7. In what ways are inference rules (for example, *modus ponens*) similar to, and different from, syntactic rules discussed in Chapter 10?

## KEY TERMS

analogical reasoning
believability effect
bias
componential approach to the study of reasoning
confirmation bias
content effect
contradiction
deductive reasoning
deductive validity
everyday reasoning
fallacy
formal reasoning
inductive reasoning
inductive strength
logical connectives
mental models approach to the study of reasoning
premise
propositional reasoning
rules/heuristics approach to the study of reasoning
syllogistic reasoning
tautology
truth table

## CogLab DEMONSTRATIONS

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

CogLab, a web-based set of demonstrations in cognitive psychology, provides a demonstration of the **Wason Selection Task** mentioned in the chapter.

## WEB RESOURCES

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

## CHAPTER 13

# Making Decisions

**Phases of Decision Making**
  Setting Goals
  Gathering Information
  Structuring the Decision
  Making a Final Choice
  Evaluating

**Basic Concepts of Probability**

**Cognitive Illusions in Decision Making**
  Availability
  Representativeness
  Framing Effects
  Anchoring
  Sunk Cost Effects
  Illusory Correlation
  Hindsight Bias
  Confirmation Bias
  Overconfidence

**Utility Models of Decision Making**
  Expected Utility Theory
  Multiattribute Utility Theory

**Descriptive Models of Decision Making**
  Image Theory
  Recognition-Primed Decision Making

**Improving Decision Making**

You've arrived at your sophomore year of college and realize you must soon declare a major—and perhaps a minor. What cognitive processes do you use to consider the options, evaluate your priorities, and make a choice?

Cognitive psychologists use the term *decision making* to refer to the mental activities that take place in choosing among alternatives. In the instance just given, the decision about an undergraduate major often is part of a larger set of decisions about a career and future life. Typically, decisions are made in the face of some amount of *uncertainty.* It is not 100% certain, say, how well you will do in the courses required for various majors, or how well you will like them, or how much various majors will help you obtain a good job after graduation. You will not know for sure if you will enjoy the faculty who teach the courses you have not yet taken, or if the topics will be interesting or useful, or if they will be relevant to your long-term goals and aspirations.

Nonetheless, at some point you have to decide. At the college where I teach, students who seek my advice in choosing a major often appear in my office showing unmistakable signs of agitation, nervousness, and confusion. They know they need to decide but don't know how. They wish the uncertainty over, but they don't want to close off options prematurely. They are aware that a lot of information relevant to the decision exists but don't know quite how to collect, organize, and use it all in the time allotted. They know there are no guarantees but don't want to make an unfortunate choice.

The dilemma is familiar to anyone who has had to make a significant and difficult life choice. The degree of uncertainty is vexing. So, too, is the number of conflicting goals and objectives. The sophomore student typically wants not only a major that is interesting but also one in which she shows some aptitude, enjoys the faculty and other students who are majoring in the same field, and sees some relevance to a future job and some flexibility for future career paths.

The number of options available also comes into play. Many schools have more than 25 majors available (some have many more). There are also options to double-major, declare minors, participate in off-campus study programs, and so on, adding complications. The amount of information that is potentially relevant can quickly grow to be staggering, in which case the decision maker needs some help in organizing it all.

Because decisions are often made under conditions of uncertainty, some don't yield the hoped-for results, even if made carefully and after thorough, unbiased consideration of the evidence. Psychologists generally argue that "goodness" of decision making cannot be measured by the success of individual decisions—luck, for instance, often plays too big a role. Instead, the yardstick of success is often taken to be the **rationality** of the decision. Various people define this term differently, but a typical definition comes from von Winterfeldt and Edwards (1986a): Rational decision making "has to do with selecting ways of thinking and acting to serve your ends or goals or moral imperatives, whatever they may be, as well as the environment permits" (p. 2). In other words, to be rational means to consider all your relevant goals and principles, not just the first ones that come to mind. If you go to buy a new computer, and choose one that looks sleek on your desk but neglect other goals—speed, reliability, availability of software, for example—you are undercutting your own decision making. Rational decision making also involves gathering information as painstakingly and fairly as possible under the circumstances. It requires you to examine not only evidence that supports your initial inclinations but also evidence that does not.

We will look at descriptions of how people gather and use information in making decisions. Many of these descriptions will show how decision making falls short of optimality. Psychologists have argued that the lack of optimality stems, in large part, from **cognitive overload**—when the information available overwhelms the cognitive processing available. Strategies for coping with information overload, though often useful, can lead to error and irrationality. Next, we will examine what people do after they have gathered the evidence, how all the pieces are put together. Finally, we will look briefly at ways of improving decision making.

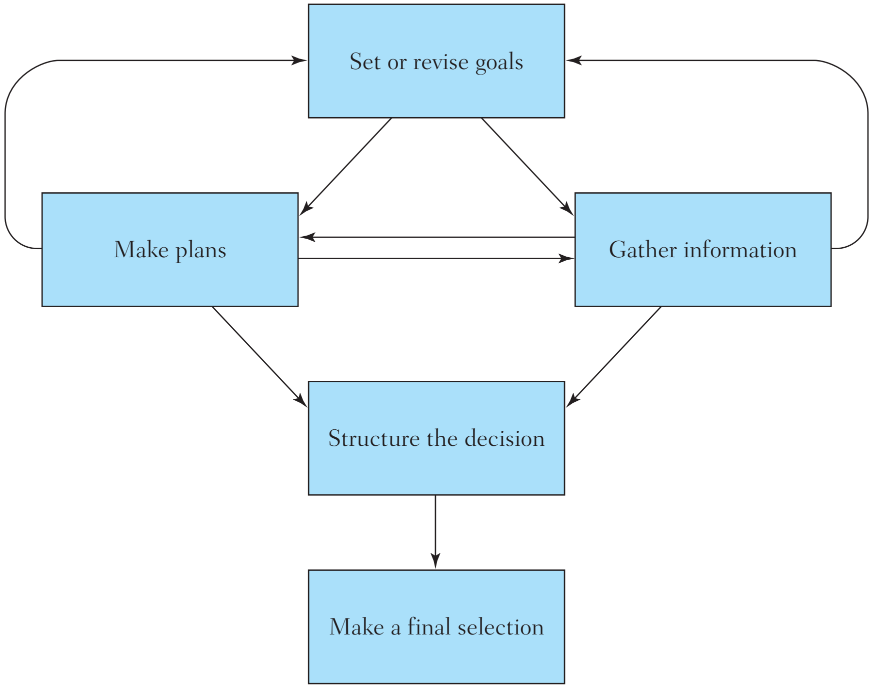
## ■ PHASES OF DECISION MAKING

We can divide decision making tasks into five different categories (Galotti, 2002). Figure 13-1 provides a schematic view. These tasks often occur in a particular order, but there may be "cycles" to an order, in which certain tasks are revisited and redone, as depicted by the arrows in the figure.

I use the term *phases* of decision making to convey the ideas that there may or may not be a set order to the tasks, that the performance of one task can overlap with the performance of another, that some tasks can be skipped, and that tasks can be done in different orders.

**FIGURE 13-1** ■ *Phases of decision making.*

**SOURCE:** Galotti (2002, p. 97).



## Setting Goals

When we try to understand why a person makes one decision rather than another, it often turns out that the reasons have to do with the decision maker's *goals* for the decision (Bandura, 2001; Galotti, 2005). Many students I talk with describe their plan to declare a biology major, because their goal is to go into medical school. Others tell me they are thinking about economics, because they want to get into a competitive corporate training program. (As it turns out, such majors aren't required, or even necessarily prized by the organizations in question, many of which value a variety of majors, but we'll leave that issue aside for now.)

The idea in setting goals is that the decision maker takes stock of his or her plans for the future, his or her principles and values, and his or her priorities. That is, the decision maker needs to develop answers to the question "What am I trying to accomplish?" Those answers are the decision maker's goals, and they influence decision making in various ways.

## Gathering Information

Before making a decision, the decision maker needs information. Specifically, she or he needs to know what the various options are. For example, what are the likely consequences of each option, both short- and long-term? Who is affected in each option, and how? Do the effects change over time? Will taking or not taking a particular course of action obligate the decision maker to other decisions or plans? In other words, does each option open or close off other options?

Some decisions can be highly complex. For example, consider the decision of which computer to buy. In any given year, there are many models available. If you also consider all the different ways a given computer can be customized, the options multiply rapidly. Somehow, the decision maker needs to gather some information about at least some of the options.

In addition to information about options, decision makers may need or want to gather information about possible criteria to use in making their choice. If you've never bought a computer before, you might talk with computer-savvy friends, or people in your company's IT department, to get information about what features they consider important. Or you might try to develop your own "wish list" of features that an ideal computer for you would have, based on your goals.

## Structuring the Decision

For complex decisions, decision makers need a way of organizing all their information. This is especially true when there are a great number of options, and when there are lots of considerations to be used in making the decision.

Consider again the example of choosing a college major. In one of my studies, I surveyed first-year college students over a period of a year as they thought about this decision (Galotti, 1999). Many of the students I surveyed listed a wide variety of criteria they considered in making this decision. Among these criteria were considerations such as "Do I enjoy the material?" "Will it lead to a career I am interested in?" "Does it have a lot of requirements?" "Do I like the faculty who teach the classes?" In the study, students listed about seven different criteria and about four different options, or possible majors. To really consider all these criteria and options, a typical decision maker will need to think about 28 different pieces of information (for example, "Is biology a subject I enjoy?" "Is chemistry a subject I enjoy?" "Is psychology a subject I enjoy?").

Twenty-eight different things to think about is quite a lot. Somehow the decision maker needs to determine or invent a way of managing this information. The way she or he does this is called **decision structuring.**

## Making a Final Choice

After gathering all the information he or she is going to gather, the decision maker needs to select from among the final set of options. This may involve a

Justin Sullivan/Getty Images

*Real-life decisions, like buying a car, are often difficult because of the number of criteria and alternatives available.*

procedure as simple as flipping a coin or throwing a dart at a wall, or it may be considerably more complex. This process may involve other decisions—such as deciding when to cease the "information-gathering" phase of the main decision or deciding which information is more relevant or reliable.

### Evaluating

A helpful (and often omitted) last phase of decision making is an evaluation of the entire process. What went well? What didn't go so well? The aim here is to reflect on the process and identify those aspects that could be improved, as well as those that ought to be used again for similar decisions in the future.

With this overview, let's take a more detailed look at some of the processes involved in decision making. I'm going to concentrate on the middle three—gathering information, structuring the decision, and making a final choice—largely because these are the processes most studied so far by cognitive psychologists.

Many decisions require people to assess the probability of certain events' happening or not. We'll begin our discussion of how people gather information, therefore, with a brief look at concepts of probability, and how well nonexperts use and understand them.

## ■ BASIC CONCEPTS OF PROBABILITY

As already mentioned, most difficult decisions and plans are made under conditions of uncertainty. After all, it would be no problem to decide which major to declare if you knew how your life would turn out in consequence of each available option. In this ideal case, you would simply look over all the outcomes and choose the option that led to the outcome you most preferred. Because people are rarely, if ever, in these circumstances, most real-life decisions involve estimating the chances or odds of different outcomes and events. To understand how people do this, it is necessary first to understand some concepts relevant to probability and uncertainty.

Although there are other competing interpretations (see Baron, 2000), **probability** can generally be thought of as a measurement of a degree of uncertainty (von Winterfeldt & Edwards, 1986a). Probabilities are numbers between 0 and 1, where 0 represents complete certainty that an event will not happen, and 1 represents complete certainty that it will. Intermediate values can be thought of as corresponding to intermediate levels of confidence that an event will occur. Someone who asserts the probability of an event to be .90 is saying he is very sure (though not certain) the event will take place.

Generally, people untrained in probability theory have little trouble with probabilities of either 0 or 1; they are less adept at using intermediate values of probability in a coherent way. Their use of intermediate numbers departs in significant ways from probability theory, and it is not hard to see why. What does it mean to say you are 30% sure of something, and how does that differ from 40% sure? What these numbers "mean" in the context of a real-life decision is not at all intuitive.

Probability theory treats differences in intermediate values of probability as corresponding to different gambles or lotteries. Consider a lottery in which there are 10 tickets and you have purchased 3. If the winning ticket is *randomly selected* (meaning that each of the 10 tickets has a completely equal chance to be chosen), then the probability of your winning is .3. If you were to buy another of the remaining 7 tickets, the probability would rise to .4. The difference between the probabilities of .4 and .3 corresponds to one lottery ticket in this example.

People's intuitions regarding the rules of probability theory are often "way off the mark." Baron (1988) offered the following example (do it intuitively first, then compare it to the calculations): A 30-year-old woman discovers a lump in her breast and goes to her physician. The physician knows that only about 5 in 100 women of the patient's age and health have breast cancer. A mammogram (breast X-ray) is taken. It indicates cancer 80% of the time in women who have breast cancer but falsely indicates cancer in healthy patients 20% of the time. The mammogram comes out positive. What is the probability that the patient has cancer? (Stop here and give your estimate.)

Although your intuitive estimate may be as high as 50% or 80%, calculation of the correct answer results in an answer of .17. Most people find their own intuitive estimates are much higher (sometimes four or five times higher) than the actual value. The calculation uses a formula known as Bayes's theorem, a thorough treatment of which can be found in Baron (1988).

For present purposes, the point I want to make does not require a detailed examination of the formula and its derivation. Here's an informal way to explain how to get to the value of .17. Take a random sample of 100 women of this age and health status. Of these, 5 should be expected to have cancer. Of the 5, 4 should be expected to show a positive test. That leaves 95 women who should be expected not to have cancer, of whom 19 should be expected to have a positive test result. So 4 of the 23 people with a positive test result actually have cancer. Dividing 23 into 4 yields .17.

Of course, probability estimates can differ from one person to the next, or from one time to the next. When I'm in a bad mood, my estimates of the likelihood of success in one of my ventures is much lower than when I'm happier. My more optimistic friends always seem to find successful outcomes more probable than do my pessimistic friends. For these and similar reasons, psychologists often distinguish between **subjective probabilities,** which are influenced by characteristics of the probability estimator, and *objective* probabilities, which are not. Of course, in many real-life circumstances there may be no objective probabilities available.

## COGNITIVE ILLUSIONS IN DECISION MAKING

How do people gather the information they will use to make a decision? Often the information comes from their own memories. Students choosing a major, for instance, may think back to their experiences in different courses or to things they have heard older students say about their experiences in different majors. Once information is gathered, the decision maker must decide on the importance and/or relevance of each piece of information. If you don't care about becoming a biologist, for instance, the information on the biology department's course offerings may not seem very important to you. The way people gather and assess the relevance of different pieces of information is the topic of this section.

Research on people's decision-making skills and styles has consistently demonstrated the existence of certain systematic and common **biases,** ways of thinking that lead to systematic errors. Typically, the biases are understandable and often justifiable ways of thinking under most conditions but can lead to error when misapplied. These systematic biases have been labeled **cognitive illusions** (von Winterfeldt & Edwards, 1986b). The term itself is meant to invoke the analogy to perceptual illusions: errors of cognition that come about for understandable reasons and that provide information relevant to understanding normal functioning. We can and do consider these illusions "errors," in the sense that one's percept does not correspond with what's really there. However, these illusions are not used as evidence that the whole perceptual system is faulty and unreliable. Rather, illusions (perceptions under certain specific conditions) tell us something about the way the perceptual system works generally—what cues are attended to, how they are interpreted, and so forth.

In a similar way, errors in decision making tell us something about the ways people gather, sort, and integrate the information they use for making a choice. The cognitive illusions described next also give us information on when unaided human decision making is likely to be optimal and when it is not. Finally, these descriptions can help us design and implement educational programs or interventions to improve the quality of decisions and plans people make.

Just what is a cognitive illusion? Von Winterfeldt and Edwards (1986b) specified that something counts as a cognitive illusion only if there is a "correct" way of answering a question or making a decision, there is also an intuitive estimate or decision, and there is a discrepancy between the two that always goes in the same direction. Answers that randomly fluctuate around the correct value, then, do not count as illusions.

## Availability

Consider the problems in Box 13-1, and give your first intuitive response to each before reading further. Tversky and Kahneman (1973) presented problems such as these to undergraduate students. The general findings were that people's intuitions were systematically wrong. In Problem 1, for instance, the letter *L* occurs more frequently in the third position than in the initial position. In Problems 2 and 3, the A and B options have the same number (of committees in the former case, and of paths in the latter).

### Box 13-1 Problems Demonstrating Availability

1. Consider the letter *L*. In the English language, is this letter more likely to appear in the first position of a word or the third position of a word? Give your intuition or "gut reaction."
2. Ten students from a nearby college have indicated a willingness to serve on a curriculum committee. Their names are Ann, Bob, Dan, Elizabeth, Gary, Heidi, Jennifer, Laura, Terri, and Valerie.
    a. The dean wants to form a two-person committee. What is your estimate of the number of distinct committees that could be formed? (Don't use formulas; just respond intuitively.)
    b. The dean wants to form an eight-person committee. What is your estimate of the number of distinct committees that could be formed? (Don't use formulas; just respond intuitively.)
3. Consider the two structures shown below:

| A | B |
|---|---|
| x x | x x x x x x x x |
| x x | x x x x x x x x |
| x x | x x x x x x x x |
| x x | |
| x x | |
| x x | |
| x x | |
| x x | |
| x x | |

A *path* in a structure is a line that connects one "x" from each row, starting with the top row and finishing at the bottom row. How many paths do you think each structure has? (Again, give an intuitive estimate.)

**SOURCE:** Adapted from Tversky and Kahneman (1973, pp. 212–214).

What accounts for the errors? Tversky and Kahneman (1973) argued that when faced with the task of estimating probability, frequency, or numerosity, people rely on shortcuts or rules of thumb, known as **heuristics,** to help make these judgments easier. One such heuristic is known as the **availability heuristic**—"assessing the ease with which the relevant mental operation of retrieval, construction, or association can be carried out" (p. 208). In other words, instances (for example, particular words, particular committees, or particular paths) that are more easily thought of, remembered, or computed stand out more in one's mind. Those instances are particularly salient and hence are deemed to be more frequent or probable.

In Problem 1, it turns out to be easier to think of words that begin with *l* (such as *lawn, leftover,* and *licorice*) than to think of words that have *l* as the third letter (*bell, wall, ill*). The reason for this may stem from the way our lexicons, or "mental dictionaries," are organized or with how we learn or practice words—alphabetically by the first letter. As with paper or electronic dictionaries, it's relatively easier to search for words by initial letter than by "interior" letters.

In Problem 2, the appropriate formula for determining the number of distinct committees that can be formed is $10!/\{(x!)([10-x]!)\}$, where $x$ is the size of the committee. Notice that for $x = 2$, $10 - x = 8$, and that for $x = 8$, $[10 - x] = 2$, implying there should be an equal number of two-person committees and eight-person committees (namely, 45). Tversky and Kahneman (1973) argued that two-person committees are more distinct. There are five two-person committees with no overlap in membership, but any two eight-person committees will have at least some overlap. Distinctiveness makes different committees easier to think of. Therefore, two-person committees are more available (because they are more distinctive) and hence deemed more numerous. You can easily see, however, that two-person and eight-person committees must be equally numerous. Consider that every two-person committee defines an eight-person noncommittee, and vice versa.

The same kind of analysis applies to Problem 3. The number of paths in either structure is given by the formula $x^y$, where $x$ is the number of $x$'s in a row and $y$ is the number of rows. The number of paths in structure A, then, is $8^3 = 512$. The number of paths in structure B is $2^9$, also equal to 512. Again, though, it is easier to see more nonoverlapping paths in A than in B; different paths in A are less confusable than different paths in B. Paths in A are shorter and therefore easier to visualize than those in B. The ease of visualization makes paths more available and hence deemed more numerous in A than in B.

Everyday analogs that involve the use of the availability heuristic have also been reported. Ross and Sicoly (1979), for instance, surveyed 37 married couples (husbands and wives separately and independently) about the estimated extent of their responsibility for various household activities, such as making breakfast, shopping for groceries, and caring for children. Husbands and wives both were more likely to say they had greater responsibility than did their spouse for 16 of the 20 activities. Moreover, when asked to give examples of their own and their spouse's contributions to each activity, each spouse listed more of her or his own activities than activities of her or his spouse.

Ross and Sicoly (1979) explained these findings in terms of the availability heuristic. Our own efforts and behaviors are more apparent and available to us than are the efforts and behaviors of others. After all, we are certain to be present when we perform an action, but we may or may not be when a friend or spouse does. Our own thoughts and plans are important to us, and we may be formulating them just at the time when other people do or say something, thus distracting us from their contributions. In general, what we do, think, say, or intend is more accessible to us than to anyone else and also more accessible than anyone else's deeds, thoughts, words, or intentions. Small wonder, then, that in joint ventures each partner often feels she or he shoulders a greater share of the burden.

Availability can be both an efficient and effective heuristic. If we can be sure that ease of constructing or calling instances to mind is unbiased, then it may be the best, or even only, tool to use when judging frequency or probability. If you are trying to decide which course you typically do more papers for, psychology or philosophy, it probably is fair to judge the frequency of papers by trying to recall specific paper assignments for each course. In this case, there is probably no particular reason to believe psychology papers are more memorable than philosophy papers. If there is (for example, you took philosophy three years ago but psychology this semester), then the comparison is probably not fair.

However, if you are trying to decide which occurs more often, hours you spend working on a group project or hours someone else spends working on the same project, using availability to judge may be unfair. You have been there whenever you have worked, but you may not have been there all the times when other group members have worked. And even if you had been there, you probably would have been paying more attention to your own work and planning than to your partners' work and planning. Thus examples of your own work are likely to be more memorable and more available to you than examples of anyone else's work.

The point of demonstrating the availability heuristic, then, is not to warn you away from its use. Instead, as with all other heuristics, the idea is to suggest you think carefully first about whether the range of examples you are drawing from is equally accessible.

## Representativeness

Two students, Linda and Joe, are having a boring Saturday afternoon in the student union. For lack of something better to do, they each begin flipping a quarter, keeping track of the way it lands over time. Then they compare results. Linda reports that her sequence of coin flips was heads, heads, heads, tails, tails, tails. Joe gets the following results: tails, tails, heads, tails, heads, heads. Which student has obtained a more statistically probable series of results?

Most people who respond to this question intuitively believe Joe did. After all, his sequence of responses is less patterned and more "random looking." In fact, however, both outcomes are equally likely. The problem is that people generally expect that a random *process,* such as a coin flip, will always produce results that are random looking. That is, they expect the results to be representative of the process that generated them. People who make judgments this way are said to be using the **representativeness heuristic.**

Kahneman and Tversky (1973) demonstrated people's use of the representativeness heuristic in a series of studies. In one study, undergraduate participants were assigned to three conditions. Those in the *base rate* condition were told, "Consider all first-year graduate students in the United States today. Please write down your best guesses about the percentage now enrolled in each of the following nine fields of specialization." The nine fields are shown in Box 13-2. Those in the *similarity* condition were presented with the personality sketch shown in Box 13-2(A) and were asked to rank the nine fields in terms of "how similar Tom W. is to the typical graduate student in each of the following nine fields of graduate specialization." Participants in the *prediction* condition were also given the personality sketch but were told it was written several years ago, during Tom W.'s senior year of high school, based on his response to projective tests (such as the Rorschach test). They were then asked to predict the likelihood for each field that Tom W. was currently a graduate student in it.

Box 13-2(B) shows that the mean similarity rankings are very similar to the mean likelihood rankings, and independent of the mean judged base rate, again suggesting use of the representativeness heuristic. Participants who had been asked to estimate the likelihood that Tom W. is a graduate student in field *X* do so, apparently, by comparing his personality description to their beliefs about what typical graduate students in field *X* are like, ignoring base rates. Base rates are important information, however. Just as in the mammogram example given earlier, the failure to include base rate information in your estimates of probability can lead to answers that are in error, often by an order of magnitude or more.

A related error in judgment is called the **gambler's fallacy.** Imagine yourself standing beside a roulette wheel in Atlantic City. You watch the wheel come up red on eight successive trials. Assuming you are still willing to believe the wheel is equally likely to come up black as it is to come up red, where would you place a bet for the next spin? Many people would bet on black, reasoning that if black and red are equally likely, then the previous outcomes have skewed the process a bit and it is now "black's turn." However, on the next trial the chances of black are exactly the same as the chances of red. The wheel is

## Box 13-2 Data From a Prediction Study

***(A) Personality sketch of Tom W.***

Tom W. is of high intelligence, although lacking in true creativity. He has a need for order and clarity, and for neat and tidy systems in which every detail finds its appropriate place. His writing is rather dull and mechanical, occasionally enlivened by somewhat corny puns and by flashes of imagination of the sci-fi type. He has a strong drive for competence. He seems to have little feel and little sympathy for other people and does not enjoy interacting with others. Self-centered, he nonetheless has a deep moral sense.

***(B) Estimated base rates of nine areas of graduate specialization, and summary of similarity and prediction data for Tom W.***

| *Graduate Specialization Area* | *Mean Judged Base Rate (in %)* | *Mean Similarity Rank* | *Mean Likelihood Rank* |
|---|---|---|---|
| Business administration | 15 | 3.9 | 4.3 |
| Computer science | 7 | 2.1 | 2.5 |
| Engineering | 9 | 2.9 | 2.6 |
| Humanities and education | 20 | 7.2 | 7.6 |
| Law | 9 | 5.9 | 5.2 |
| Library science | 3 | 4.2 | 4.7 |
| Medicine | 8 | 5.9 | 5.8 |
| Physical and life sciences | 12 | 4.5 | 4.3 |
| Social science and social work | 17 | 8.2 | 8.0 |

**SOURCE:** Kahneman and Tversky (1973, p. 238).

not "keeping track" in any way of past results, so it is not going to "correct" or "make up for" past results. Although *in the long run* the number of times black comes up should equal the number of times red comes up, this does not mean that in the short run the proportions will be even. This explanation applies also to the coin-flipping example given earlier. A random process (such as a coin flip or a roulette wheel spin) will not always produce results that look random, especially in the short run.

Tversky and Kahneman (1971) described people's (mistaken) belief in the *law of small numbers.* The idea is that people expect small samples (of people, of coin flips, of trials in an experiment) to resemble in every respect the populations from which they are drawn. In actuality, small samples are much more likely to deviate from the population and are therefore a less reliable basis on which to build a conclusion than are larger samples. The gambler's fallacy problem can be thought of as an instance of belief in the law of small numbers.

Dennis MacDonald/ Photoedit

*Gambler's fallacy can cause people to make biased decisions.*

People expect that a small sample of roulette wheel spins (such as 8) will show the same proportion of reds as will a very large sample (such as 100,000). However, the chances of finding large deviations from the expected proportion are much greater with a small *N* sample. Said another way, only very large samples can be expected to be representative of the population from which they come. Sedlmeier and Gigerenzer (2000) explored the issue of people's intuitions about sample size in greater depth, arguing that people sometimes do have correct intuitions about sample size, but often don't.

"Man who" arguments are another example of the misuse of the representativeness heuristic. The term was coined by Nisbett and Ross (1980). A "man who" argument is usually advanced by someone who has just confronted, for instance, a statistical summary of a number of cases reporting that lung cancer rates are significantly higher among smokers than nonsmokers. The reply "I know a *man who* smoked three packs a day and lived to be 110" is a particularly vivid example of ignoring base rate information and instead paying as much attention to small sample sizes (the individual man who was known, $N = 1$) as to large ones (those cases summarized, where $N$ may be 10,000 or more).

## Framing Effects

Driving down the road, you notice your car is running low on gasoline, and you see two service stations, both advertising gasoline. Station A's price is $2.00 per gallon; station B's, $1.95. Station A's sign also announces, "5 cents/gallon discount for cash!" Station B's sign announces, "5 cents/gallon surcharge for credit cards." All other factors being equal (for example, cleanliness of the stations, whether you like the brand of gasoline carried, number of cars waiting at each), to which station would you choose to go? Many people report a preference for Station A, the one that offers a cash discount (Thaler, 1980).

It is interesting that people have this preference, because both stations are actually offering the same deal: a price of $1.95 per gallon if you use cash and $2.00 per gallon if you use a credit card. Tversky and Kahneman (1981) explained this phenomenon in terms of **framing effects:** People evaluate outcomes as changes from a reference point, their current state. Depending on how their current state is described, they perceive certain outcomes as gains or losses. The description is therefore said to "frame" the decision, or to provide a certain context for it. We have already seen with previous cognitive topics (such as perception, thinking, reasoning) that context effects can play a large role in affecting cognitive performance. Framing effects, in essence, can be thought of as context effects in decision making.

Here's what appears to be going on in the gas station example. Described as a "cash discount," the price seems a bargain—you assume you are starting from a reference point of $2.00 a gallon and then saving or gaining a nickel. In the case of station B, however, you describe the situation to yourself as follows: "OK, so they're charging $1.95. Sounds good. But hey, wait a minute. If I want to use my card, they'll jack up the price to $2.00. Hey, I'd lose a nickel a gallon that way. What rip-off artists they are! Heck, I'll just go to station A." Kahneman and Tversky (1979) argued that we treat losses more seriously than we treat gains of an equivalent amount (whether of money or of some other measure of satisfaction). That is, we care more about losing a dollar than we do about gaining a dollar, or more about losing a nickel than gaining a nickel.

The problem is that simply changing the *description* of a situation can lead us to adopt different reference points and therefore to see the same outcome as a gain in one situation and a loss in the other. That in turn may lead us to change our decision, not because anything in the problem has changed but simply because the way we describe the situation to ourselves has changed.

## Anchoring

Suppose I ask you to answer a numerical question with an estimate (assuming you don't know the exactly correct value): As of April 2000, what was the population of Philadelphia? (I'll give you the correct answer later.) Imagine I give two people, call them Tim and Kim, this question, but I give each one a "starting value," obtained by spinning a roulette wheel. Now, Kim and Tim watch me spin the wheel, and they know that it operates (and stops) purely by chance and that the "starting value" is arbitrary. Kim's starting value is 1 million; Tim's, 2 million. If they are like most research participants in Tversky and Kahneman's (1973) study, Kim will arrive at an estimate of 1.25 million; Tim, 1.75 million. In other words, their initial starting point will have a huge effect on their final estimates, showing evidence of the phenomenon known as **anchoring.** (The correct value is 1,517,550, according to the April 1, 2000, U.S. Census.)

Likewise, consider two groups of high school students, each given five seconds to estimate a complex expression. Group 1 estimates 8 × 7 × 6 × 5 × 4 × 3 × 2 × 1, and reports a mean estimate of 2250; Group 2 estimates 1 × 2 × 3 × 4 × 5 × 6 × 7 × 8, and reports the answer to be (on average) 512. As you can tell, both problems are identical. You probably are not able to tell this quickly, but both estimates are too small: The correct value is 40,320.

Tversky and Kahneman (2000) explain these results this way: People tend to perform the first few steps of multiplication, then extrapolate. The extrapolation tends to be too little rather than too much. That explains the fact that both groups of participants underestimated the answer. In addition, those who started with 1 × 2 × 3 began with a smaller value than did those who began with 8 × 7 × 6, so the first group more severely underestimated the result.

## Sunk Cost Effects

A major educational initiative is begun in your hometown; $3 million is invested to help students stay away from cigarettes, liquor, and other drugs. In the third of four years, evidence begins to accumulate that the program is not working. A local legislator proposes ending funding to the program before the scheduled date. Howls of protest go up from some individuals, who claim that to stop a program after a large expenditure of funds has been spent would be a waste. These individuals are falling prey to what Arkes and Blumer (1985) have dubbed the **sunk cost effect:** "[the] greater tendency to continue an endeavor once an investment in money, effort, or time has been made" (p. 124).

Why is this an error? The explanation goes something like this: Money spent is already gone. Whether or not a great deal of money (or time, or energy, or emotion) has been spent does not affect the likelihood of future success. Those resources have been used, regardless of which option is chosen. All that should affect a decision, therefore, are the expected future benefits and costs of each option (Arkes & Hutzel, 2000).

## Illusory Correlation

You and a friend, both students of (if not majors in) psychology, observe fellow students around campus and discover a behavioral pattern you call "hair twisting": The person pinches a strand of hair between thumb and forefinger and proceeds to twist it around the forefinger. You believe this behavior is especially likely in people undergoing a great deal of stress. Needing a research paper for your psychology class, you undertake a study with your friend. You observe a random sample of 150 students for a day, categorizing them as hair twisters or not hair twisters. (Assume that you and your friend make your observations independently and that your interrater reliability, the agreement of categorization between you two, is high.) Later, each participant is given a battery of psychological tests to decide whether he or she is under significant amounts of stress. The results are shown in Box 13-3. Given these data, give your intuitive estimate of the relationship between stress and hair twisting. If you have had a course in statistics, you can try estimating the correlation coefficient or chi square test of contingency statistic; if not, try to put into words your belief about how strong the relationship is.

## Box 13-3 Example of Illusory Correlation

| | *Under Stress* | *Not Under Stress* |
|---|---|---|
| Hair twister | 20 | 10 |
| Not a hair twister | 80 | 40 |

Given the data above, give your intuitive estimate of the correlation between the two variables (from 0 to 1).

I posed this question to 30 students taking a cognitive psychology course. Most believed there was at least a weak relationship between the two variables. In fact, there is absolutely no relationship. Notice that the proportion of hair twisters is .25 (20/80 and 10/40) for both the participants under stress and the participants not under stress. Nevertheless, my students' intuitions are typical: People report seeing data associations that seem plausible even when associations are not present. In this example, hair twisting and stress are plausibly related because hair twisting sounds like a nervous behavior and because nervous behaviors are likely to be produced under conditions of anxiety.

The phenomenon of seeing nonexistent relationships is called **illusory correlation.** Notice that in the example given, it occurs even under ideal conditions (all the data are summarized and presented in a table, so you do not need to recall all the relevant cases from memory). There is no ambiguity over where individual cases fall (everyone is classified as a hair twister or not, and under stress or not), and there is no reason to expect personal biases on your part to interfere with your estimate. The data are dichotomous (that is, yes or no) for both variables and therefore easy to work with.

Chapman and Chapman (1967a, 1967b, 1969) presented an even more compelling demonstration of the phenomenon of illusory correlation. The authors were puzzled by a controversy within the field of clinical psychology over the use of the Draw-a-Person Test. This is a psychodiagnostic test in which the client is asked to "draw a person" and the drawings are scored according to a number of dimensions (for example, whether the figure drawn is muscular, has atypical eyes, is childlike, is fat). Clinicians had reported strong correlations between some of the features of drawings and particular symptoms and behavioral characteristics (for example, atypical eyes as being drawn by suspicious clients; big heads as being drawn by intelligent clients). However, these reports were never confirmed by researchers studying the test itself.

In one study, Chapman and Chapman (1967a) gave undergraduates who were unfamiliar with the Draw-a-Person Test a series of 45 drawings that they randomly paired with symptoms allegedly displayed by the people who drew them. These undergraduates "discovered" the same correlations that clinicians had been reporting. Because the drawings and symptoms were randomly paired, it appeared the undergraduates shared with the clinicians a preexisting bias as to what relationships would be found in the data. That is, they "discovered" relationships they expected to find, even when no such relationships were there.

Variables that tend to be falsely associated typically seem to have some prior association in people's minds (Chapman & Chapman, 1967b). On the surface, it seems to make sense that suspicious clients might draw wide-eyed figures: The wide eyes might be an artistic or symbolic representation of their suspiciousness. The point here is that the associations we bring to a situation often color our judgment to such as extent that we see them even if they are not there.

## Hindsight Bias

Consider the following decision: You need to choose between declaring a psychology major and an economics major. You consult your own performance, goals, likes, and dislikes and have long discussions with faculty in both departments, majors in both departments, teachers from both areas who have instructed you, friends, parents, and relevant others. You finally decide to become an economics major, primarily because of your interest in the topics in your classes and also because you like the economics faculty so much.

A few months later you start to discover you like your economics classes less and less, and you find your psychology courses more interesting than you previously had. You reopen the decision about your major, spend another couple of weeks rethinking your goals and interests, and decide to switch majors to psychology. When you announce this decision to your best friend, she says, "Well, I knew this was going to happen. It was pretty much inevitable. You don't seem the type to fit in with the other majors in that department, and also, given the stuff you said about last term's assignments, I knew you wouldn't like it for long." Other friends of yours also express little surprise at your latest decision, confiding that they "knew all along" that you would change your major.

How is it that you yourself didn't foresee this inevitable change in majors? How is it that your friends could see into your future and you could not? In fact, one likely answer is that your friends are in error and that they are suffering from something called **hindsight bias.** Fischhoff (1982b) described this bias as a tendency to "consistently exaggerate what could have been anticipated in foresight" when looking back (in hindsight) on an event (p. 341). The idea is that once you know how a decision has turned out, you look back on the events leading up to the outcome as being more inevitable than they really were.

Fischhoff (1975) demonstrated hindsight bias experimentally in the following way. Participants were asked to read a passage similar to the one shown in Box 13-4. Passages described either historical events (as does the one in Box 13-4) or clinical case descriptions of people. All participants were asked to rate the likelihood of a number of possible outcomes of the event. Some

## Box 13-4 Example of Hindsight Bias

Read the following passage, then answer the question below:

> [1] For some years after the arrival of Hastings as governor-general of India, the consolidation of British power involved serious war. [2] The first of these wars took place on the northern frontier of Bengal where the British were faced by the plundering raids of the Gurkas of Nepal. [3] Attempts had been made to stop the raids by an exchange of lands, but the Gurkas would not give up their claims to country under British control, [4] and Hastings decided to deal with them once and for all. [5] The campaign began in November 1814. It was not glorious. [6] The Gurkas were only some 12,000 strong; [7] but they were brave fighters, fighting in territory well suited to their raiding tactics. [8] The older British commanders were used to war in the plains where the enemy ran away from a resolute attack. [9] In the mountains of Nepal it was not easy even to find the enemy. [10] The troops and transport animals suffered from the extremes of heat and cold, [11] and the officers learned caution only after sharp reverses. [12] Major-General Sir D. Octerlony was the one commander to escape from these minor defeats.

In light of the information appearing in the passage, what was the probability of occurrence of each of the four possible outcomes listed below? (The probabilities should sum to 100%.)

______British victory

______Gurka victory

______Military stalemate with no peace settlement

______Military stalemate with a peace settlement

**SOURCE:** Fischhoff (1975, p. 289).

were additionally told which one of the outcomes had actually occurred and were asked to estimate (in hindsight) the probabilities of all the possible outcomes.

Results showed that participants who were told what the outcome actually was gave higher estimates of the probability that it would have happened, given the description in the passage, than did those who were not told what outcome had occurred. Surprisingly, participants saw as inevitable the outcome that they were told had happened, regardless of which outcome it was. Participants who were told that the British won saw British victory "all along" in the passage; those who were told that the Gurkas won saw that outcome as inevitable. Those who were told that the clash ended in a military stalemate also said that they saw that outcome coming.

How does hindsight bias apply to your friends in the hypothetical situation just described? Recall that they told you they "knew all along" that your decision to major in economics would not turn out well. It is likely, however, that your friends are looking back in hindsight, knowing how your original decision turned out, and are therefore more able to think of reasons that your decision turned out this way. Their ability to predict, in foresight, how your decision would turn out is probably far weaker. In short, to quote an old maxim, "Hindsight is always 20/20." Recent investigations, by the way, have demonstrated the occurrence of hindsight bias in real-life contexts, with participants' (mis)recollections of such events as the economic effects of the introduction of the Euro (Hoelzl, Kirchler, & Rodler, 2002), the impeachment verdict regarding President Clinton (Bryant & Guilbault, 2002), and the outcome of the O. J. Simpson trial (Demakis, 2002).

## Confirmation Bias

In my hometown, parents can place their public school children in one of seven options for first grade. Parents of kindergartners, therefore, spend a lot of time and energy trying to find the "best" option for their child. Some parents do this by talking to other parents. For example, parents interested in the Spanish-immersion option may seek out other parents who have children enrolled in the immersion program, and ask if they like it. After a prospective parent has talked to, say, five happy Spanish-immersion parents, their own sense grows that the immersion program is right for their child.

What's wrong with that, you may ask? Who better to tell a parent what the experience is like than another parent? Well, the name for the way in which the prospective parent is gathering information is called **confirmation bias,** discussed in Chapter 12. This is the tendency to search only for information that will confirm one's initial hunch or hypothesis, and to overlook or ignore other information.

Parents go wrong if they *only* seek information that would potentially confirm their hunch that a particular option is the best. If they only talk to parents of children in the program, they talk to parents most likely to be happy customers of the program. (If they weren't happy with the program, then presumably those parents would have placed their children in other programs.) The most rational decision, then, would be made by talking to a randomly selected set of parents, or to parents who have transferred out of a particular option, as well as to parents with children still in that option.

## Overconfidence

Consider the questions in Box 13-5, and choose from the two possible answers. After answering, give a rating of your confidence. If you have absolutely no idea of what the answer is, choose the value .5, to indicate that you think the odds you are right are 50–50. (Any number lower than .5 would indicate you think you are more likely to be wrong than right, so you should have chosen the other answer.) A rating of 1.00 means you are 100% certain your answer is correct. Values between .5 and 1.00 indicate intermediate levels of confidence, with higher numbers reflecting higher confidence.

### Box 13-5 Some Trivia Questions

Choose one answer for each question, and rate your confidence in your answer on a scale from .5 (just guessing) to 1.0 (completely certain).

Which magazine had the largest circulation in 1978?
a. Time    b. Reader's Digest

Which city had the larger population in 1953?
a. St. Paul, MN    b. New Orleans, LA

Who was the 21st president of the United States?
a. Arthur    b. Cleveland

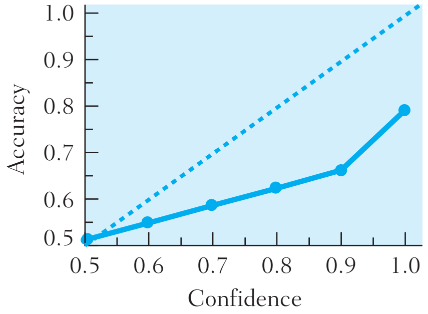
Which Union ironclad ship fought the Confederate ironclad ship Merrimack?
a. Monitor    b. Andover

Who began the profession of nursing?
a. Nightingale    b. Barton

For the purposes of this discussion, it matters very little how accurate your answers are. (If you simply *must* have the correct answers, they are b, a, a, a, a.) What matters here is the relationship between your accuracy and your confidence rating. In several studies (reviewed by Lichtenstein, Fischhoff, & Phillips, 1982), participants were given a long list of questions similar to those in Box 13-5. After they answered all the questions and gave confidence ratings, their accuracy was plotted as a function of their confidence ratings. For example, the experimenters looked at all the questions for which a participant rated his confidence as .6 and calculated the proportion of those questions he answered correctly.

Typical findings are shown in Figure 13-2. Notice that the 45-degree line would indicate that confidence and accuracy were perfectly synchronized: Questions for which a participant had a confidence rating of .6 would actually be answered accurately 60% of the time. This kind of finding is rarely, if ever, found. Instead, typical curves are "bowed" out from the 45-degree line, as shown in the figure.

**FIGURE 13-2** ■ *Example of a calibration curve. (The dotted line indicates perfect calibration.)*



This kind of curve—plotting confidence against accuracy—is called a **calibration curve.** The closer the curve is to the 45-degree line, the better the calibration, or "fit," between confidence and accuracy. Deviations from the curve below this line are said to indicate **overconfidence,** where confidence ratings are higher than actual accuracy. Deviations above the line would indicate *underconfidence,* a phenomenon that rarely occurs. The general idea is this: For all the questions to which participants give a .8 confidence rating (meaning they estimate the probability of their answering correctly as 80%), they are correct only about 60% of the time. Further, when participants say they are 100% certain of the answer, they are correct only about 75% to 80% of the time.

Said another way, people's impressions of their own accuracy are inflated. Overconfidence is a real impediment to good decision making. If your confidence in your judgment is inappropriately high, you probably will spurn any offers of help in making decisions because you will fail to see the need for it. Even when good decision aids are available to help you overcome other biases and errors of judgment, overconfidence will make you weight your own intuitions more heavily than any objective information that might be available. Overconfidence, then, can be thought of as arrogance in decision making.

So far, we have reviewed a (very incomplete) list of heuristics and biases in decision making and planning. Again, the point here is not that these ways of gathering and assessing information are always wrong or bad. Instead, the examples point out places where decision making does not go as smoothly as it could. The existence of these biases also tells us something about how human beings "naturally" cope with information, particularly when information is in abundance. Documenting such errors can be the first step to setting up effective remedial programs.

## ■ UTILITY MODELS OF DECISION MAKING

The previous section described errors and patterns of thinking that people use when gathering information. Another issue, though, is how people sift through all the gathered information to reach a decision. In this section, we will review two models that describe, or purport to describe, exactly what people are doing when they structure a decision and choose from alternatives.

It will be useful first to describe in a more general way the kinds of models of decision making (and thinking) that exist. **Normative models** define ideal performance under ideal circumstances. **Prescriptive models** tell us how we "ought" to make decisions. They take into account the fact that circumstances in which decisions are made are rarely ideal, and they provide guidance about how to do the best we can. Teachers try to get students to follow prescriptive models. **Descriptive models,** in contrast, simply detail what people actually do when they make decisions. These are not necessarily endorsements of good ways of thinking; rather, they describe actual performance. The distinctions among normative, prescriptive, and descriptive models are important as we consider various specific theories.

### Expected Utility Theory

Making a decision such as choosing a major can be compared to a gamble. In most gambles, you win (or lose) particular amounts of money depending on certain outcomes. Probability theory tells us (assuming fair coins, decks of cards, and the like) what the odds are of any outcome. The dollar amount won or lost tells us the monetary worth of each outcome.

It would be nice if we could somehow combine information about probabilities and amounts that can be won or lost. In fact, one way is to calculate the *expected value* of each outcome. By multiplying the probability of each outcome by the amount of money won or lost for that outcome and summing these values over all possible outcomes, we can determine the expected value of the gamble. Presumably, then, if we were offered a choice between two gambles, we could choose the better one by calculating the expected value of each and choosing the gamble with the higher value.

This idea of expected value can be expressed in the form of an equation,

$$(1)\ EV = \Sigma(p_i \times v_i)$$

where $EV$ stands for "expected value" of the gamble, $p_i$ is the probability of the $i$th outcome, and $v_i$ is the monetary value of that outcome. For example, imagine a lottery with ten tickets numbered 1 through 10. If the ticket drawn is numbered 1, you win $10. If the ticket drawn is numbered 2, 3, or 4, you win $5. Any other numbers drawn are worth nothing. The *EV* of this lottery, then, is

$$(.1 \times \$10) + (.3 \times \$5) + (.6 \times \$0) = \$1.60$$

What good does it do you to calculate the expected value? For one thing, it provides you with a guide to how much money (if any) you should be willing to spend to buy a lottery ticket. If you are making rational decisions, you should not spend more for the ticket than the expected value of the lottery. (In some lotteries for charity, of course, you may want to donate more money simply to support the cause. In that case, you would need to add the expected value of the lottery and the amount of money you are willing to donate.)

Not every decision involves monetary outcomes. We often care about other aspects of possible outcomes: our chances for happiness, success, or fulfillment of goals. Psychologists, economists, and others use the term **utility** to capture ideas of happiness, pleasure, and the satisfaction that comes from achieving one or more personal goals. A choice that fulfills one goal has less utility than a choice that fulfills that same goal plus another. For these decisions, we can use the kind of equation just given, using utility instead of monetary value. Equation 1 now becomes

$$(2)\ EU = \Sigma(p_i \times u_i)$$

where $EU$ stands for the "expected utility" of a decision and $u_i$ is the utility of the $i$th outcome. The summation is again over all the possible outcomes.

Let's translate our original example of choosing a major into the *EU* model. Imagine that you have listed all possible majors, estimated the probability of success in each, and determined your overall utility for success or failure. Table 13-1 provides an example. You estimate you have a good chance of success in some majors (such as sociology). You do not think you have much chance of success in others (perhaps physics). At the same time, you place different values on success in various majors. In this example, you value psychology the most, followed by chemistry and biology. Your utility for failure also differs among the possible majors. For some, your overall utility even for failure is positive (such as biology, mathematics). For others, your overall utility for failure is strongly negative (such as psychology, sociology). The last column

**Table 13-1** An Example of Expected Utility Calculations for the Decision to Major in Selected Subjects

| Major | Probability of Success | Utility For Success | Utility For Failure | Expected Utility |
|---|---|---|---|---|
| Art | .75 | 10 | 0 | 7.50 |
| Asian studies | .50 | 0 | –5 | –2.50 |
| Biology | .30 | 25 | 5 | 11.00 |
| Chemistry | .45 | 30 | 4 | 15.70 |
| Economics | .15 | 5 | –10 | –7.75 |
| English | .25 | 5 | 0 | 1.25 |
| French | .60 | 0 | –5 | –2.00 |
| German | .50 | 0 | –5 | –2.50 |
| History | .25 | 8 | 0 | 2.00 |
| Mathematics | .05 | 10 | 5 | 5.25 |
| Philosophy | .10 | 0 | –5 | –4.50 |
| Physics | .01 | 0 | 0 | 0.00 |
| Psychology | .60 | 35 | –20 | 13.00 |
| Religion | .50 | 5 | –5 | 0.00 |
| Sociology | .80 | 5 | –25 | –1.00 |

Note: The probability of each outcome (success and failure) is multiplied by the utility for each outcome, and summed across both, giving the overall expected utility of choosing that major. Probabilities and utilities come from the individual making the decision and are subjective estimates.

gives the overall expected utility for each major. It suggests that the best decision, given the estimates of probability and utility, is a chemistry major, with psychology and biology as second and third choices, respectively.

You may be wondering how utility is measured in this example. The measurement of utilities is turns out to be fairly straightforward. If you select one outcome and assign it the value of 0, then you can assign other values using this as the reference point. It does not matter which outcome is chosen as the zero point, because the final decision depends on differences in *EU*s, not on the absolute value of the utilities (see Baron, 1994, for more on this process).

Many see **expected utility theory** as a normative model of decision making. It can be shown (see Baron, 2000) that if you always choose so as to maximize expected utility, then over a sufficiently large number of decisions, your own satisfaction will be highest. In other words, there is no better way of choosing among options that in the long run will increase overall satisfaction than using EU.

## Multiattribute Utility Theory

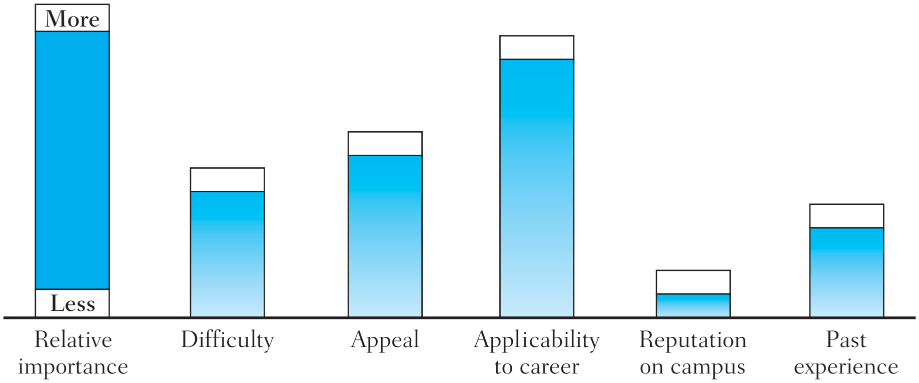
Like many others, you may feel that using EU theory to choose a major oversimplifies the decision. Specifically, you may find it hard to quantify your utility for success or for failure of any specific major. You may care about several goals and find it hard to figure out how they all fit together.

In two studies (Galotti, 1999; Galotti & Kozberg, 1987), undergraduates were asked to list the factors they had thought about (or, in the case of freshmen and sophomores, that they were thinking about) when they chose a major. Respondents listed a number of things, among them difficulty and appeal. One problem in making this decision appeared to involve how the various factors and goals were integrated. Calculating *EU,* using Equation 2, may be difficult because information about several aspects of the decision must be integrated. Fortunately, there is a model that provides a means of integrating different dimensions and goals of a complex decision. It is called **multiattribute utility theory (MAUT).**

MAUT involves six steps: (1) breaking a decision into independent dimensions (for choosing a major, these might include difficulty, appeal, applicability to career, reputation on campus, and past experience); (2) determining the relative weights of each dimension; (3) listing all the alternatives (such as possible majors); (4) ranking the alternatives along the five dimensions; (5) multiplying the ranking by the weighting of each alternative to determine its final value; and (6) choosing the alternative with the highest value.

Figures 13-3 through 13-6 provide an example of MAUT applied to the decision of choosing a major, created with the computer program Decision Map (Kopp & Slayter, 1984). Look first at Figure 13-3, the first two steps in MAUT. It shows the five dimensions listed in the previous paragraph, along with weightings that a particular student might give. (Again, weightings indicate how important a given aspect of the decision is to the decision maker.)

**FIGURE 13-3** ■ *Weightings of five dimensions in the decision "choosing a major."*



For this student, the most important goal is choosing a major relevant to future career goals. Notice that in the graph, the goal or dimension "applicability to career" has the highest value and hence the most weight. The next most important goals, for this student, are the appeal of the major, its difficulty, and the student's past record of success in its courses. The goal "reputation on campus" has been given very little weight by this student, indicating that it is of relatively little importance. Of significance here is that these weights are subjective and would change for different students. Your own weightings could be very dissimilar to the ones given in this example.

After weighting all the dimensions, the decision maker must consider all the alternatives and assess them on all the dimensions described in the previous paragraph. Figure 13-4 depicts part of this process: the ranking of various majors on the dimension "applicability to career." To simplify the example, only the top four potential majors from Table 13-1 are shown here: chemistry, psychology, biology, and art. The student would need to rate each of these alternatives on each of the dimensions identified in the first two steps. There would thus be five graphs of this kind, one for each dimension identified in Figure 13-3.

**FIGURE 13-4** ■ *Assessment of four possible majors on one dimension in the decision "choosing a major."*

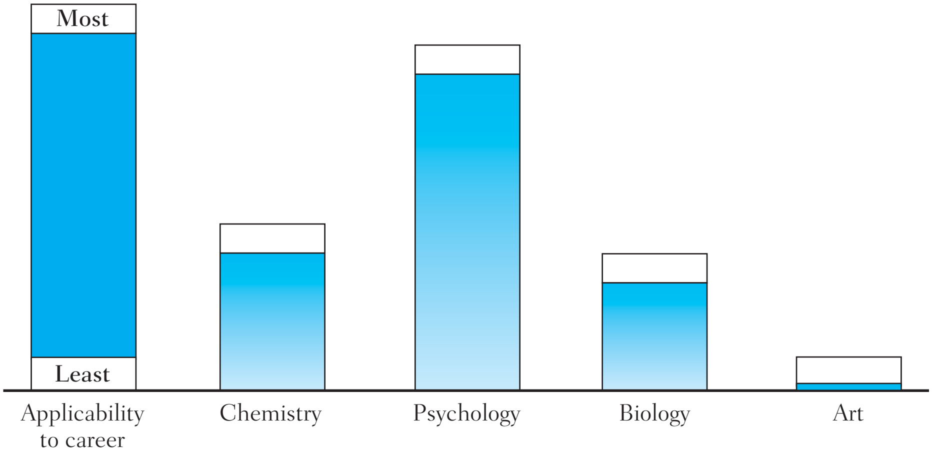


Figure 13-5 depicts the fifth step in the MAUT process: putting together the assessments of alternatives on all the dimensions, together with the weights of those dimensions. It shows that psychology is the best alternative, according to the rankings and weightings given earlier. Figure 13-6 provides an analysis of why this is so: Psychology far outranks other alternatives on the dimension "applicability to career" and is not very far below other alternatives on the other dimensions.

**FIGURE 13-5** ■ *Final choice of a major.*

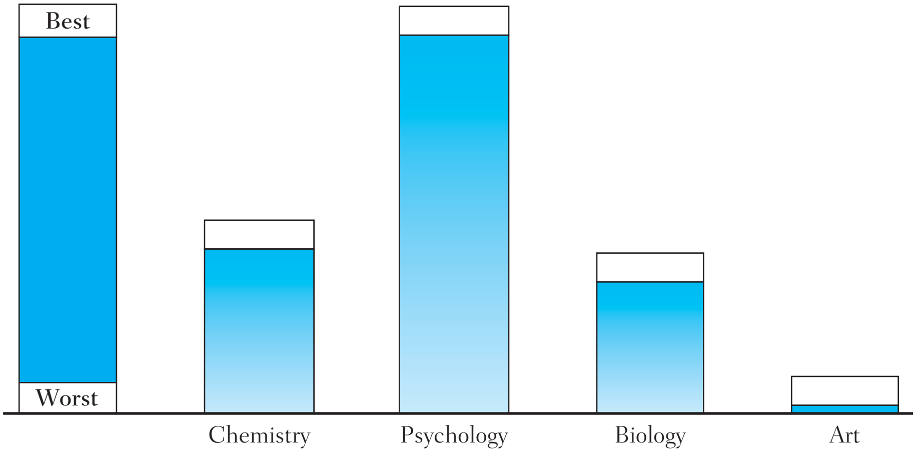
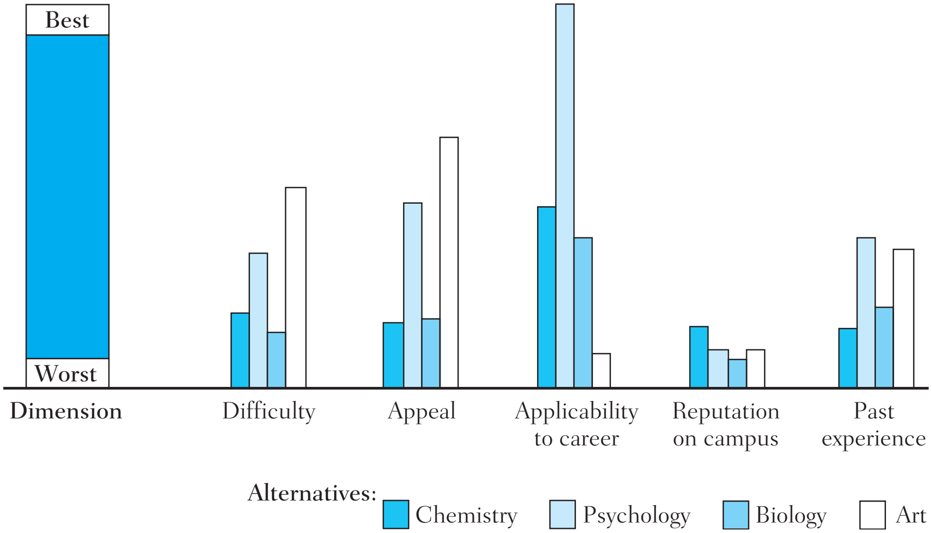


**FIGURE 13-6** ■ *An analysis of the decision "choosing a major."*

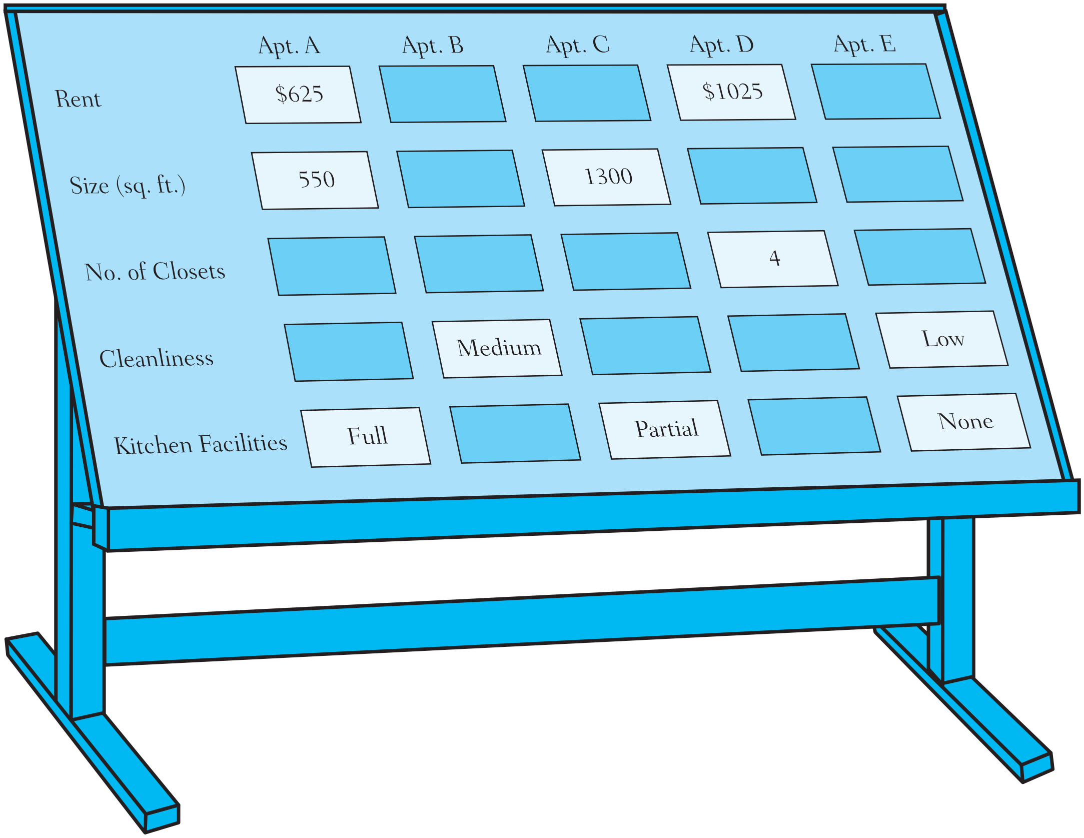


To use MAUT in decision making, it is critical that the dimensions listed be independent of one another. For instance, the possible dimensions "difficulty of courses" and "past grades in course" are presumably related. Thus the decision maker must choose each dimension carefully. The decision maker then must be willing to make tradeoffs among the various dimensions. Although the decision maker in our example cares most about future career goals, MAUT assumes the person would be willing to choose an alternative that was not highest on this dimension *if* its relative position on other dimensions was high enough to compensate.

I asserted earlier that many psychologists see MAUT as a normative model of decision making (although there are other views, discussed later). That is, if people follow MAUT they will maximize their own utility in a way that is best for achieving all their goals. Unfortunately, little is known about whether people ever use MAUT spontaneously when making important decisions, especially if the information relevant to making the decision is extensive.

A study by Payne (1976) suggests that people do not always use MAUT. Payne examined how people chose apartments when given different amounts of information about different numbers of alternatives. Participants were presented with an "information board" carrying a number of cards, as depicted in Figure 13-7. Each card represented a different one-bedroom furnished apartment and carried the name of a factor, such as "noise level," "rent," or "closet space." The back of the card gave the value of that dimension for that apartment; possible values for the rent factor, for example, were $110, $140, or $170.

**FIGURE 13-7** ■ *Depiction of an information board.*



Participants could examine one piece of information at a time (for example, the rent for apartment 1) and could examine as many or as few pieces of information as they needed to make a decision. The experimenter kept track of which pieces of information were examined. Two factors were varied in the experiment: the number of alternatives (that is, apartments) presented—2, 6, or 12; and the number of factors of information available per alternative—4, 8, or 12.

When choosing between only two apartments, participants examined the same number of factors for each. That is, if they asked about rent, closet space, parking, and laundry facilities for one, they asked about rent, closet space, parking, and laundry facilities for the other. They were willing to make tradeoffs in this decision, letting a desirable value of one factor (such as low rent) trade off against a less desirable value of another (such as less closet space).

When participants had to decide among 6 or 12 apartments, however, they used another strategy. In these cases, they eliminated some alternatives on the basis of only one or a few dimensions. For instance, they looked first at rent and immediately eliminated all apartments with high rents, without considering tradeoffs with other factors. This strategy has been called **elimination by aspects** (Tversky, 1972). It works as follows: First a factor is selected, say, rent. All the alternatives that exceed a threshold value for this factor (for example, more than $140) are eliminated. Next another factor is selected—say, noise level—and any alternatives found to exceed a threshold value on that dimension (for example, very noisy) are eliminated. This process continues until only one alternative is left. Payne (1976) believed that when decision makers have too much information to deal with, they reduce "cognitive strain" by resorting to such nonoptimal heuristics as elimination by aspects.

MAUT is a normative model; elimination by aspects is a descriptive model. It provides a picture of what people actually do. Whether elimination by aspects is the best one can do, with limited time or memory, to make a decision is an open question. In some cases, it may be entirely rational. If an apartment seeker simply cannot afford a rent above a certain amount, then it makes no sense to expend energy considering apartments that cost more, regardless of how well they rate on other dimensions. In other cases, it may be important for decision makers to take the time and trouble to engage in a MAUT analysis. Various kinds of decision aids (including computer-assisted ones) exist and may prove useful.

## ■ DESCRIPTIVE MODELS OF DECISION MAKING

As I implied earlier, not all investigators regard EU theory as normative. Frisch and Clemen (1994) offered several shortcomings of EU theory. The first is that EU theory provides an account only of making the final selection from a set of alternatives, not of making decisions in which one faces a "status quo" versus "make a change" option. Moreover, EU theory does not describe the process(es) by which people *structure* a decision—that is, gather information and lay out the possibilities and parameters.

## Image Theory

A more recently proposed descriptive model of decision making, quite different from EU models, is that of **image theory** (Beach, 1993; Beach & Mitchell, 1987; Mitchell & Beach, 1990). The fundamental assumption of this theory is that in making real-life decisions, people rarely go through a formal structuring process in which they lay out all their options and criteria and then weigh and integrate various pieces of information, as MAUT and other EU models predict. Instead, most of the decision-making work is done during a phase known as the "prechoice screening of options." In this phase, decision makers typically winnow the number of options under active consideration to a small number, sometimes one or two. They do this by asking themselves whether a new goal, plan, or alternative is compatible with three images: the *value image* (containing the decision maker's values, morals, and principles), the *trajectory image* (containing the decision maker's goals and aspirations for the future), and the *strategic image* (the way in which the decision maker plans to attain his or her goals).

To return to our example of choosing a major, image theory might describe the college student as "trying on for size" various majors. That student might quickly reject certain majors because they aren't perceived as fitting well with the student's values or principles (for example, "I can't major in economics because all econ majors care about is money"). Alternatively, options might be dropped from further exploration if they don't fit well with the student's view of his or her own future (for example, "Art history? No way. I don't want to end up driving a taxi for life") or the path a student plans to take to achieve his or her future vision (for example, "If I want to go to med school, an English lit major isn't going to help me much"). (By the way, I use these quotes as examples of what students say, but I don't endorse the ideas they express: I know philanthropists who were econ majors, art history majors who went on to lead financially successful lives, and English lit majors who became physicians!)

According to image theory, options judged incompatible with one or more of these three images (value, trajectory, strategic) are dropped from further consideration. This prechoice screening process is noncompensatory: Violations of any image are enough to rule out that option, and no tradeoffs are made. Screening may result in a single option remaining active; in this case the decision maker's final choice is simply whether to accept the option. If there is more than one survivor of the prechoice screening phase, then the decision maker may go on to use a compensatory (i.e., making tradeoffs) or other decision strategy to make the final choice. If there are no survivors, decision makers presumably attempt to discover new options.

Image theory offers some intriguing ideas to researchers studying real-life decision making. Some preliminary work supports it, but more studies are needed to fully assess how well it captures the early processes of decision making.

## Recognition-Primed Decision Making

Researcher Gary Klein (1998) studied experts making time-pressured, high-stakes (often life-or-death) decisions: firefighters, intensive care pediatric nurses, military officers. What he found was that few of their decision processes were captured by utility-like models, with the listing and evaluating of several options simultaneously. Instead, he argues, experts are most likely to rely on intuition, mental simulation, making metaphors or analogies, and recalling or creating stories. Klein and his associates expanded these studies into a series of investigations they dub "naturalistic decision making" (Lipshitz, Klein, Orasanu, & Salas, 2001), and the model they created is called **recognition-primed decision making.**

Much of the work in expert decision making is done, Klein argues, as the experts "size up" a situation. As they take stock of a new situation, they compare it to other situations they've previously encountered, calling to mind narrative stories about what happened in those situations and why. Typically, Klein found, experts consider one option at a time, mentally simulating the likely effect of a particular decision. If that simulation fits the scenario, the decision maker implements it; if not, she tries to find either another option or another metaphor for the situation. Box 13-6 provides an example in which a firefighter describes a sort of "sixth sense" he had in arriving at a decision.

### Box 13-6 Example of Real-Life Expert Decision Making

It is a simple house fire in a one-story house in a residential neighborhood. The fire is in the back, in the kitchen area. The lieutenant leads his hose crew into the building, to the back, to spray water on the fire, but the fire just roars back at them.

"Odd," he thinks. The water should have more of an impact. They try dousing it again, and get the same results. They retreat a few steps to regroup.

Then the lieutenant starts to feel as if something is not right. He doesn't have any clues; he just doesn't feel right about being in that house, so he orders his men out of the building—a perfectly standard building with nothing out of the ordinary.

As soon as his men leave the building, the floor where they had been standing collapses. Had they still been inside, they would have plunged into the fire below.

**SOURCE:** Klein (1998, p. 32).

## IMPROVING DECISION MAKING

We have reviewed evidence suggesting that two major components of decision making—the gathering and integration of information—are typically performed less than optimally (Tetlock, 2002). These studies therefore raise the question "How can these activities be improved?" In this section, we will look at the major reasons that decision making goes awry and suggest some ways of eliminating the problems or at least reducing their impact.

One of the major obstacles to improving the ways in which people gather and integrate information is overconfidence. People who believe their decision making is already close to optimal simply will not see the need for any assistance, even if it is available and offered. Such people may not even seek or look at evidence regarding their performance. Overconfidence, then, is a twofold problem because of its effects in particular decisions and because it inflates people's view of their own decision-making and planning capabilities.

In general, simply telling people about biases in decision making and planning (including overconfidence) results in little or no improvement (Arkes, 1986; Fischhoff, 1982a). Real improvement in reducing bias seems to require extensive practice with the task, individual feedback about one's performance, and some means of making the statistical and/or probabilistic aspects of the decisions clearer. Under some of these conditions, substantial reductions in bias have been reported (Arkes, 1986; Nisbett, Krantz, Jepson, & Kunda, 1983).

Nisbett et al. (1983) found, for instance, that making certain aspects of a situation more salient increases people's tendency to reason statistically. In one study, they presented people with one of two versions of a problem (shown in Box 13-7) about a high school senior making college decisions. Version 2 was intended to highlight the fact that what David L. saw during his campus visit was simply a subset, or sample, of all the things he could have possibly seen and thus depended to some degree on chance. Participants reading Version 2 apparently took account of the role of chance in David L.'s visit, because they were significantly less likely to say he should go to the Ivy League university (and thus ignore his friends' advice, which is presumably based on a much larger sample of information than the sample David L. received from his own visit) than were participants who read Version 1. The implication is that making the role of chance in a situation more obvious encourages people to weight information in ways that reduce bias and error.

In other studies (reviewed by Nisbett et al., 1987), Nisbett and his collaborators found that even relatively brief, 30-minute training sessions in statistical reasoning could improve people's ability to apply statistical principles to everyday life. Apparently, then, certain kinds of training can improve at least some aspects of decision making.

## Box 13-7 Sample Stimuli From Nisbett et al. (1983)

***Version 1***

David L. was a senior in high school on the East Coast who was planning to go to college. He had compiled an excellent record in high school and had been admitted to his two top choices: a small liberal arts college and an Ivy League university. David had several older friends who were attending the liberal arts college and several who were attending the Ivy League university. They were all excellent students like himself and had interests similar to his. The friends at the liberal arts college all reported that they liked the place very much and that they found it very stimulating. The friends at the Ivy League university reported that they had many complaints on both personal and social grounds and on educational grounds.

David initially thought that he would go to the smaller college. However, he decided to visit both schools himself for a day.

He did not like what he saw at the private liberal arts college: Several people whom he met seemed cold and unpleasant; a professor he met with briefly seemed abrupt and uninterested in him; and he did not like the "feel" of the campus. He did like what he saw at the Ivy League university: Several of the people he met seemed like vital, enthusiastic, pleasant people; he met with two different professors who took a personal interest in him; and he came away with a very pleasant feeling about the campus.

***Version 2 (Same as Version 1, with the following material added after the second paragraph)***

He proceeded systematically to draw up a long list, for both colleges, of all the classes which might interest him and all the places and activities on campus that he wanted to see. From each list, he randomly selected several classes and activities to visit, and several spots to look at (by blindly dropping a pencil on each list of alternatives and seeing where the point landed).

**SOURCE:** Nisbett et al. (1983, p. 353).

A second obstacle to improving decision making has to do with people's feelings and expectations about how decisions ought to be made. Cultural expectations lead many of us to trust our intuitions (or at least the intuitions of experts) over any kind of judgment made with equations, computer programs, mathematical models, or the like. This preference is especially evident with very important decisions. We want to be sure that decisions concerning, say, job or graduate school applicants, medical diagnoses and treatments, or even mortgage loans, are made humanely—taking all relevant evidence into account and not just looking at numbers.

Meehl (1954, 1965) confronted this issue some years ago. He examined the relative effectiveness of holistic, clinical impressions with judgments made by statistical models of data. A good example would be to compare an admissions counselor's prediction of an applicant's chances for success at a given college with the prediction of a statistical model that weighted SAT scores, high school GPA, degree of involvement in extracurricular activities, strength of letters of recommendation (however measured), and whatever other variables were established to be relevant to predicting success at that college. Numerous studies of this kind overwhelmingly support use of the nonhuman model (Dawes, 1982; Dawes & Corrigan, 1974). Thus, contrary to our (strong) intuitions, it *is* often better, fairer, more rational, and in the long run more humane to use decision aids than to rely exclusively on human impressions or intuitions (Kleinmuntz, 1990).

Does this mean that all decisions should be made by computer? On the contrary, people will always be needed to select and judge the relevance of the information to be used in a decision. Dawes (1982) argued that people are quite proficient at figuring out *which* variables are good predictors. Human shortcomings show up when people try to integrate all the information relevant to a decision. Linear models (such as the ones used in Figures 13-3 through 13-6), in contrast, are good at integrating information that human judges have selected as relevant. **Decision analysis** (Keeney, 1982; von Winterfeldt & Edwards, 1986b) is an emerging technology that helps people gather and integrate information in a way similar to that used earlier in the MAUT analysis of choosing a major. It uses human judges' feelings, beliefs, and judgments of relevance but helps ensure that integration of information is carried out in an unbiased way.

Despite all the literature documenting people's errors in judgment and decision making, people do make decisions every day. It is therefore worth remembering that any good theory of decision making must explain how people have survived thus far and where the sources of people's competence lie. At the same time, it is probably safe to conclude that complex and important decisions can usually be made more carefully.

Decision making is a relatively new topic for cognitive psychology. Therefore, we can expect to learn a great deal more about it in the years to come. This kind of research will not only produce better models of the ways in which people process and use information but, it is hoped, help in the long run to improve these skills.

## SUMMARY

1. Decision making requires setting goals; gathering information; organizing, combining, and evaluating information; and making a final selection.
2. Because real-life decisions are often made under conditions of uncertainty, many decisions require some sort of probability estimates, even if only vague and intuitive ones. Research reviewed in the chapter suggests that people's

understanding of concepts relating to probability theory is often vague or weak, especially for probabilities that are not exactly equal to either .00 or 1.00.

3. Because the process can be so complex, it is perhaps not surprising that decision making can go wrong or be suboptimal in a number of ways. People's intuitions about uncertainty and probability, their activities to acquire or remember relevant information, and the processes they use to integrate different pieces of information can easily be shown to be error prone. You can think of at least some biases and errors in decision making as cognitive illusions: They arise for understandable reasons and may actually be quite useful in some circumstances. For example, using availability to estimate the relative frequency of something may work perfectly well as long as you can be sure that examples have been collected in an unbiased fashion.
4. The existence of framing effects suggests that the way people evaluate options often is inappropriately colored by the way they describe (or "frame") those options. If the description frames the status quo in a positive light, then people see changes as more risky and shy away from those options; the converse is true if the status quo is defined in more negative terms.
5. One of the most general biases that people typically exhibit is overconfidence in their own judgment. Several demonstrations make the point that people often feel much more sure of their thinking and their predictions for the future than is justified (on the basis of their track records, for instance). Overconfidence can also play a role in more specific biases, such as hindsight bias and illusory correlation. In general, overconfidence can prevent people from critically examining their own thinking or from admitting of possibilities other than their favored one.
6. Some normative models of decision making purport to show how people *should* make decisions under ideal circumstances. One example is multiattribute utility theory (MAUT), which describes how information about the probability and the utility of various possible outcomes can be combined and compared.
7. Other, descriptive models describe how people *actually* make decisions. One such model, elimination by aspects, assumes that the amount of information people seek depends on the number of alternative possibilities under consideration. Another descriptive model of decision making, image theory, places more emphasis on the initial phases of decision making, the screening of options, than on the later stages of decision making, in which one option is selected. Recognition-primed decision making, a model developed from studies of experts, suggests that much of the work of decision making is done when an expert "sizes up" a decision situation.
8. Decision analysis, a collection of techniques to help people consider all relevant options and tradeoffs, can improve the quality of decision making.

## REVIEW QUESTIONS

1. What are the major phases of decision making?
2. Why do some psychologists regard heuristics and biases in decision making as "cognitive illusions"?
3. Give two examples of the use of the availability heuristic in everyday life—one example where it would be appropriate and another example where it might not. Show why your examples are illustrative of availability.
4. Give an explanation for the illusory correlation phenomenon. Discuss the implications of your explanation.
5. Discuss the relationship between hindsight bias and overconfidence.
6. What is a calibration curve? Illustrate your answer with a diagram and text explaining the relevant features.
7. Explain the distinctions among normative models, prescriptive models, and descriptive models of thinking.
8. What is expected utility theory, and how does it relate to decision making?
9. Describe image theory, and contrast it with EU theory.
10. What are the major similarities and differences between image theory and the recognition-primed model of decision making?
11. What do studies of clinical impressions and intuitions imply about decision making? Do you accept these implications? Why, or why not?

## KEY TERMS

anchoring
availability heuristic
bias
calibration curve
cognitive illusions
cognitive overload
confirmation bias
decision analysis
decision structuring
descriptive model of decision making
elimination by aspects
expected utility (EU) theory
framing effect
gambler's fallacy
heuristic
hindsight bias
illusory correlation
image theory
multiattribute utility theory (MAUT)
normative model of decision making
overconfidence
prescriptive model of decision making
probability
rationality
recognition-primed decision making
representativeness heuristic
subjective probability
sunk cost effect
utility

## CogLab DEMONSTRATIONS

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

Framing effects, discussed in this chapter, are clearly illustrated in the **Risky Decisions** demonstration. The **Typical Reasoning** demonstration illustrates another reasoning bias described by Tversky and Kahneman, the conjunctive fallacy. The **Monty Hall** demonstration is based on an old TV game show, *Let's Make a Deal,* and illustrates people's basic misunderstandings of probability theory.

## WEB RESOURCES

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

# PART V

# Individual and Situational Differences in Cognition

14 Cognitive Development Through Adolescence
15 Individual, Aging, and Gender Differences in Cognition
16 Cognition in Cross-Cultural Perspective

CHAPTER

# 14

# Cognitive Development Through Adolescence

**Piagetian Theory**
- General Principles
- Stages of Development
- Reactions to Piaget's Theory

**Non-Piagetian Approaches to Cognitive Development**
- Perceptual Development in Infancy
- Toddlers' Acquisition of Syntax
- Preschoolers' Use of Memorial Strategies
- Conceptual Development in Early Childhood
- The Development of Reasoning Abilities in Middle and Late Childhood

**Some Post-Piagetian Answers to the Question "What Develops?"**
- Neurological Maturation
- Working-Memory Capacity and Processing Speed
- Attention and Perceptual Encoding
- The Knowledge Base and Knowledge Structures
- Strategies
- Metacognition

A little more than 13 years ago, an infant son came into my life. Despite my delight in this arrival, I have to admit that his limited behavioral and communicative repertoire made the very early months sometimes frustrating and stressful. His frequent crying often gave no clue as to the source of his problem, and it was hard to know if he was happy, sad, mad, or glad (to paraphrase Dr. Seuss) to be in the world.

Sixty-odd months later, I was parenting a son who could print his name, tell unsuspecting strangers long tales of his life (real and pretend), invent pretend schools (at which his imaginary teacher was Cinderella and his imaginary coach scheduled six basketball games a day), argue with great sophistication over bedtime and mealtime rules, and remember details of trips and conversations that had occurred months earlier.

As I write this edition, I travel this journey again with my almost 5-year-old daughter. It's amazing to watch her use her abilities and confront challenges. These personal experiences, combined with my professional interest in cognitive abilities, have led me to wonder about the origins of those abilities. So far in this book, the capacities, skills, and strategies used in cognitive tasks have all been described in terms of a person who has presumably mastered or acquired most, or even all, of the skills considered necessary for a fully functioning cognitive being. It can be argued, however, that our understanding of adult cognition is fundamentally incomplete unless we understand its development. The reasons that adults use their memory, reach one conclusion rather than another, or perceive something in a certain way may have a great deal to do with their previous experience with cognitive tasks as well as with their current ability to understand the demands of the task in front of them.

In this chapter, we will pause to consider how cognitive capacities, skills, and strategies come to be—when and how they are acquired or mastered and what sorts of influences affect their growth. We will examine how infants and children at different points in their development cope with different cognitive tasks.

Our review of cognitive development will necessarily be quite selective. There simply isn't room in one chapter to consider the development of performance on all the cognitive tasks that we have previously discussed. Instead, we will first look at broad theoretical approaches to cognitive development, considering the general question "How do cognitive abilities change and grow as an infant matures through adolescence?" To do this, we will focus on two major kinds of theoretical approaches: stage theories, such as that developed by Piaget, and nonstage theories, such as information-processing models.

**Stage theories of cognitive development** are so named because they describe development as consisting of a series of qualitatively different periods, called *stages.* Each stage consists of a different way of making sense of the world. Stage theories view children as fundamentally and qualitatively different from adults in one or more respects by virtue of their being in different developmental stages. Stage theories assume that children go through stages in a fixed or stable order, never skipping stages or going backward. Presumably, the cognitive abilities and capacities gained in one stage prepare the child to acquire the abilities and capacities of the next stage. In this sense, stages build on one another. Most stage theorists also claim *universality* for their stages, seeing them as applicable to children from a wide variety of cultures and environments.

Nonstage theories of cognitive development do not see qualitative changes at different developmental periods. Instead, these theories view development as the gradual acquisition of one or more things—for example, mental associations, memory capacity, perceptual discrimination, attentional focus, knowledge, or strategies. Generally speaking, nonstage theories view children as quantitatively but not qualitatively different from adults.

After reviewing these two theoretical approaches in greater detail, we will examine cognitive development on selective specific cognitive tasks. In doing so, we will review several proposals for what children acquire and master in the course of their development. We will see that there currently are a number of distinct, although not mutually exclusive, answers to the question "What is it that develops?" (Siegler, 1978).

Developmental theories, according to Patricia Miller (1993) "have saved developmental psychology from drowning in a sea of data on children" (p. 2). Like other theories, developmental theories are organized ways of explaining phenomena. They include assumptions and predictions that can be translated into testable hypotheses. In particular, developmental theories try to explain how and why certain changes occur in children's behavior and performance at different periods. Further, developmental theories focus mainly on long-lasting changes. Miller described three specific goals of developmental theories: "(1) to describe changes within one or several areas of behavior, (2) to describe changes in the relationships among several areas of behavior, and (3) to explain the course of development that has been described" (p. 5).

There are hundreds of developmental theories in psychology. Most have a narrow focus, describing only one aspect of development (such as memory or perception), and many focus on only one developmental period (such as infancy or adolescence). Here, we will first consider one very broad developmental approach that set out to describe and explain many aspects of cognitive development over a broad time span. This approach, Piagetian theory, is arguably the single most important theory in the field of cognitive development. Next we will consider alternatives to Piagetian theory. There is not one opposing theory here but rather a collection of proposals from different researchers. Each of these usually focuses on a more limited aspect of cognitive development.

## ■ PIAGETIAN THEORY

Jean Piaget (1896–1980) was fascinated by the question of how intelligence and cognitive functions come to be. He quickly rejected the idea that intelligence consists of the passive acquisition, storage, and organization of knowledge from the environment. Nor did he accept the view that intelligence arises solely as a function of physical maturation. Instead, he saw intelligence as something that adapts to its environment over time, through the active participation of both the child and his or her environment (Piaget, 1970/1988). We will review a few general principles of Piagetian theory before describing specific cognitive stages of development.

## General Principles

Piaget's long-standing interest in the development of children's thinking actually began, in a way, in his own childhood, as he studied and wrote about birds, fossils, and mollusks. In adolescence, he added the study of philosophy to his ever-widening circle of interests. His knowledge of natural history and science led him to think about psychological concepts, such as thinking and intelligence, in very ethological terms. Specifically, Piaget saw how any organism adapts to its environment as sharing many similarities to how human children's intelligence develops. Both processes involve a sort of adaptation. Intelligence, Piaget believed, represented an adaptation of mental structures to the physical, social, and intellectual environments (Ginsburg & Opper, 1988).

Piaget saw children as active participants in their own development. He rejected the idea that cognitive structures somehow slowly emerge or unfold, or that they are thrust on an unsuspecting and passive child by a parent, teacher, or other aspect of the environment. Instead, Piaget believed that children construct their own *mental structures,* the building blocks of cognition and intelligence, through a constant and active series of interactions with their environment.

Construction of mental structures begins shortly after birth. The infant comes into the world with very little cognitive "equipment." Indeed, about all the neonate has is a set of reflexes, including such things as sucking and grasping. These reflexes (the precursors to mental structures) encounter the environment, and the interaction of the two results in the gradual growth and change of the original reflexes. Throughout the process, the infant (and later, the child, and still later, the adolescent) actively participates through practice, experimentation, and accidental discovery.

Piaget saw the major mechanism of development as the *adaptation* of mental structures. The analogy here is to evolutionary adaptation—how animals, over several generations, evolve new structures or behaviors that better fit their current environment. Adaptation in the Piagetian sense consists of two distinct but interrelated processes: assimilation and accommodation. Piaget (1970/1988) defined *assimilation* as the "integration of external elements into evolving or completed structures" (p. 7). The idea here is that mental structures are applied to new objects in the world.

An infant who has a structure (Piaget called it a *scheme*) for sucking may at first suckle only at the mother's breast. However, when new objects are placed within easy reach of his mouth, the infant may apply that structure to the new object, say, a bent finger. We say the finger has been *assimilated* to the sucking scheme.

Accommodation, by contrast, involves changing the structures to fit new objects. A finger has a different shape and texture from a breast and must be

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sucked in a slightly different way. Each time the infant sucks on a new object, she changes, even if ever so slightly, the sucking scheme. That internal change in the structure is known as *accommodation*. Assimilation and accommodation are always present, at least to some degree, in every act of adaptation, because it is impossible for one to exist in the absence of the other. Optimally, the two are balanced, or in equilibrium.

Piaget assumed that all cognitive functioning is organized in a particular manner at every level of development. By "organized," Piaget meant to suggest that the various mental structures have some relationships to one another. With development, these relationships become more complex, more numerous, and more systematic. Although some organization among mental structures always exists, the specific interrelationships of mental structures change in different developmental stages. As a result, the ways in which the child understands the world also change with development. According to Piaget, this is because knowledge is always acquired and interpreted through whatever mental structures currently exist.

## Stages of Development

Piaget described four major periods (we will refer to them here as *stages*) of development. Some of these stages can be divided into a series of substages. For our purposes, we will concentrate on the four main stages, but interested students can learn more about the substages by consulting other sources (such as Ginsburg & Opper, 1988; Miller, 2002).

### The Sensorimotor Stage

The first stage is the *sensorimotor stage,* beginning at birth and lasting roughly 18 months. The stage is so named because Piaget believed that an infant in this phase of development experiences the world almost entirely through sensory and motor experiences. According to Piaget, knowledge gained during this stage is acquired through, and is often equivalent to, sensation or action. The infant is described as lacking the capacity for mental representation. Thus all experience must happen in the here and now and must be centered on things that are present.

The implications of this description are profound. They suggest that infants experience the world in ways completely different from those of older children or adults. Older children can have thoughts, conscious recollections of past experiences, and ideas about the past and future. All these abilities, however, require the capacity for mental representation. The infant, lacking the capacity for mental representation, cannot have any of these things. For the infant, thought *is* action or sensation, because there is no means of representing thought except through action or sensation.

Piaget saw all cognitive development as beginning with the infant's biological heritage: a simple set of reflexes such as sucking and rooting (moving the head in the direction of a touch on the cheek). This primitive "mental equipment" slowly changes and evolves as the infant matures and acquires many experiences in the world. Sucking, for instance, is applied to many different objects—fingers, toys, keys, strands of hair—demonstrating assimilation of new objects to the sucking scheme. Each of these objects has a different shape, size, and texture, so the way the infant sucks on each one is slightly different, forcing accommodation of the sucking scheme.

Gradually, over a period of 18 months, the schemes grow more complex, are executed more smoothly and more efficiently, and become integrated with other developing schemes. At first, for example, infants may suck only on objects placed near their mouth. Later in infancy, they learn how to grasp objects in front of them. As these two schemes—sucking and grasping—develop, they can also be coordinated so that older infants can reach out for an interesting novel object, pull it toward them, and place it in their mouth as a new thing to suck on.

Nancy J. Ashmore

*According to Piaget, the sucking scheme demonstrated by this infant will undergo assimilation and accommodation.*

One of the important developments in the sensorimotor stage is the acquisition of the concept of *object permanence*. An adult holds a novel and interesting toy in front of a seated infant, attracting his attention. As the infant reaches for the toy, however, the adult frustrates his attempts to grab it by first moving it out of reach, then blocking the infant's view by placing a screen between the infant and the toy. The reaction of the 4-month-old infant is quite surprising: A few seconds after the toy disappears from sight, the infant looks away and shows no inclination to search for it. Piaget interpreted this reaction as follows: Having no capacity for mental representation, the infant experiences objects only when they are present in the here and now. Quite literally, objects out of sight are also objects out of mind.

An older infant (say, around 8 months) demonstrates more, if not complete, understanding of the idea that objects continue to exist even when they are not immediately in view. An infant at roughly this age continues to search for objects that are partly hidden. A slightly older infant (10–12 months) even searches for completely hidden objects. This is also about the time that infants start to show *stranger anxiety*—looking fearfully around for a parent who has left the room and showing wariness of the person left with them (often

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a hapless babysitter). The infant seems to treat the missing parent as yet another object that has disappeared—except in this case, the emotional consequences of the disappearance are much greater than they are for a ball or other toy.

Another important developmental achievement in the sensorimotor period is the increasing intentionality and understanding of causality. Piaget's description of this aspect of development (as well as other aspects) involves the concept of *circular reactions*—behaviors that are repeated over and over. At first, young infants (1–4 months) display *primary circular reactions*—behaviors that are set off by chance, are centered on the infant's own body, lead to an interesting (from the infant's point of view) result, and are then continued. Thumb sucking is an example. Young infants' thumbs find their way into their mouths almost at random. Once a thumb is properly situated, however, most infants keep it there and continue to suck on it.

*Secondary circular reactions* emerge at roughly 4 to 8 months. These are oriented to objects outside the infant's body and may include such things as shaking a rattle to produce a noise or banging the side of a crib to make a mobile attached to the crib move. At around 18 months, *tertiary circular reactions* appear. Piaget compared the infant's tertiary circular reactions to scientific experiments. Here the infant begins with a goal in mind—to produce an interesting result. For example, he may drop a toy over the side of his high chair and watch it fall. This interesting result leads the infant to experiment, varying different aspects of the situation. Different toys are dropped, from varying heights, on different sides. Other things—bottles, cups of juice, and bowls of food—can also be dropped, to the infant's glee and the caretaker's frustration.

The sensorimotor period ends after approximately 18 to 24 months. Having begun her cognitive life with little more than reflexes, the infant now has a new understanding of objects and their existence independent of her actions, a better sense of her own ability to affect things in the world, and most important, the mental ability to represent objects, events, and people. Older infants show some recall of past events. For example, one of Piaget's daughters, Jacqueline, was able at about 14 months to re-create many of the features of a temper tantrum she had seen a little boy produce 12 hours before (Miller, 2002). This event displays a number of cognitive abilities—the ability to store and recall information and the ability to imitate these behaviors at a later time (*deferred imitation*)—all of which require the existence of mental representation. All these achievements are necessary for the cognitive tasks to be confronted in the next period of development.

## The Preoperational Stage

The next stage of development, lasting from roughly age 18 months to roughly age 7 years, is known as the *preoperational stage* of cognitive development.

Armed with the capacity for mental representation, the preoperational child understands the world in new and more complex ways than did the infant or toddler. In particular, the preoperational child has acquired the *semiotic function,* the ability to use one thing to represent or stand for another. The child now shows a great deal of symbolic functioning: pretending to drink from an empty cup; cradling a doll or stuffed toy as if it were a baby; "riding" on a "pretend horse" made of a stick.

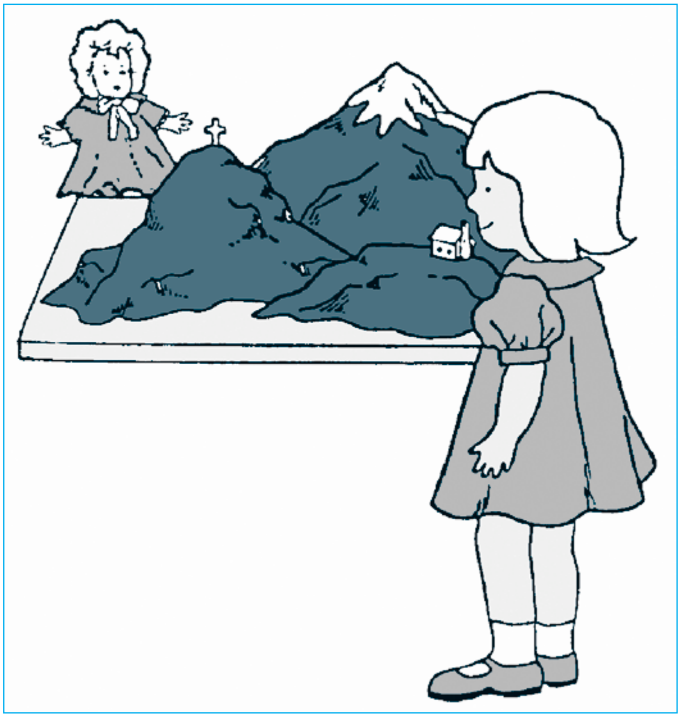
A second, and related, ability is the use of language. Children at this age are busy rapidly acquiring a vocabulary of words that "stand for" real objects or events in the world. In this sense, language requires symbolic thought capacities. Piaget saw children's language development as a reflection, rather than a cause, of their intellectual structures. The child's capacity for representational thought now allows a greater variety of cognitive activities and thus a greater range of exploration. Children can now play in more complex ways than ever before, including elements of fantasy and reenactment. They can talk with others about their experiences, those in the present and those that have previously happened. They can also talk about and begin to plan for future events, such as a trip to the store after nap time, and use language to guide themselves through challenging tasks.

At the same time, as the name of the stage suggests, there are important gaps in children's thinking. In fact, the name *preoperational* suggests a contrast with the later period of concrete operations. Preoperational children are typically described as lacking mental operations that older children have (to be described later; Gelman, 1978) and, consequently, as having significant limits on their thinking. Of course, adults have been shown throughout the book to have limits on their thinking, too. Apparently, though, the greater limitations to which children seem subject change their cognitive performance in very noticeable ways.

Piaget described the preoperational child as *egocentric* in his thinking. Children of this age apparently have a difficult time taking into account any viewpoint other than their own. For example, a 4-year-old coming home from nursery school might tell his mother, "Ted did it," not explaining who Ted is or what he did. According to Piaget, this egocentric language results from his inability to take his mother's perspective, to understand that his mother might not know who Ted is. The 4-year-old assumes that everyone knows what he knows, sees things as he does, and remembers what he remembers.

An experimental demonstration of egocentrism came from the work of Piaget and Inhelder (1967). They presented children with a three-dimensional model of three mountains. Arranged around the mountains were different objects, such as a small house and a cross, that were visible from some angles but not others. Preschool children were asked to describe whether an observer (a small wooden doll) on the other side of the table could see particular objects (see Figure 14-1). Children typically responded that the observer could see everything the child could see, failing to take into account the observer's different vantage point.

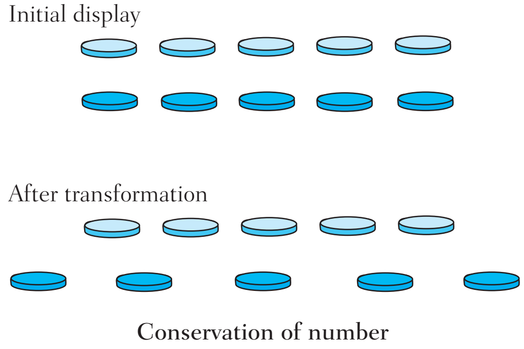
**FIGURE 14-1** ■ *Example of the stimulus apparatus for the three-mountain task.*



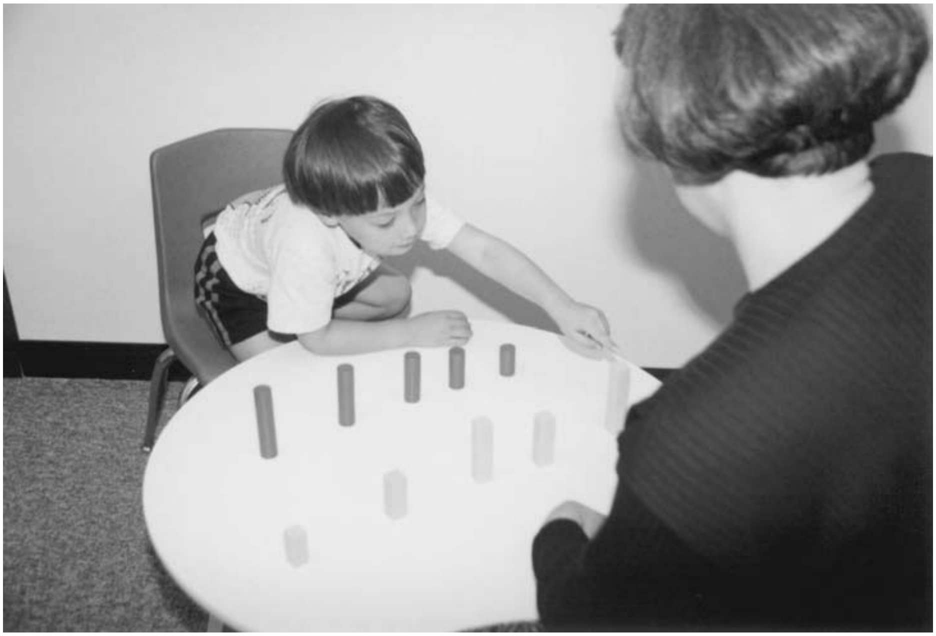
Preoperational children's thinking has also been described as *centered* on their perceptions of the world. That is, the children attend to, or focus on, only a limited amount of the information available at any given point (Ginsburg & Opper, 1988). Moreover, the thought of preoperational children is said to be *static,* focusing on states rather than transformations or changes. Finally, preoperational children are described as lacking *reversibility,* the ability to "mentally reverse" an action.

One well-known illustration of these aspects of preoperational thinking comes from Piagetian number *conservation* tasks. They work as follows: The experimenter sets two rows of checkers in front of the child, one set black and one red, each containing five checkers. Initially, the checkers in each row are set out in one-to-one correspondence (each black checker is lined up with a red checker), and the child judges both rows of checkers to be equal in number. Next the experimenter spreads out one of the rows of checkers (see Figure 14-2) and asks the child which row has more, or if the two rows still have the same number of checkers. The typical 4-year-old responds that the longer row has more checkers than the shorter row. He has not appreciated that operations such as moving checkers around the table are number irrelevant: They do not affect the numerosity of the rows.

**FIGURE 14-2** ■ *Depiction of conservation of number task.*



One explanation for this puzzling response is that the child is overwhelmed by what the two rows of checkers look like. One row does indeed look "bigger" (longer) and perhaps therefore more numerous. The child has centered on the length of the rows and ignored the density (the space between checkers) or the numerosity. The child has paid attention to what the rows of checkers now look like (the static stimulus display) and has ignored the fact that the transformation



Nancy J. Ashmore

*To a preoperational child, it might seem as though the row of pegs closer to him contains fewer than the row farther away.*

involved did not add or subtract any checkers and thus could not affect the number of checkers in either row. Finally, the child has not mentally reversed the action of spreading out one row of checkers—to see that he can mentally push the less dense row into its original formation, in which the two rows of checkers are numerically equal. According to Piaget, the things preoperational children lack—the abilities to decenter, to focus on transformations, and to reverse actions—leave them with little to rely on other than their perceptual experience.

### The Concrete Operations Stage

Children's thinking changes, again dramatically, when they move into the next stage of development, the period of *concrete operations,* around the age of 7 until about the age of 11 or 12. At this point, the child can attend to much more information than before and therefore can take into account more than one aspect of a situation. Piaget described this aspect of children's thought as *decentered,* to draw a contrast with the centered nature of preoperational thought. Concrete-operational children also can pay attention to transformations and not just to initial and final states.

The conservation task provides a familiar example. The child who conserves number moves beyond his perception, recognizing that certain changes (for example, in number, or in amount of liquid) result only from certain transformations, such as adding or taking away, and not from others, such as spreading out or changing shape. Piaget says that this child's thought shows *reversibility.* A concrete-operational child can construct (as the preoperational child cannot) a mental representation of the transformation and of the "reverse" of the transformation (moving checkers to their original position, pouring a liquid back into its original container) and can use this knowledge to judge correctly the relative numbers or amounts.

Another ability that matures during the stage of concrete operations is *classification.* The younger, preoperational child has a great deal of trouble consistently sorting a group of objects into categories (for example, all the round things, all the square things; or all the blue things, all the red things). The preoperational child has difficulty maintaining a consistent basis of classification. He may start out sorting wooden blocks on the basis of shape but midway through the task start sorting on the basis of color. The groups he ends up with will include blocks that vary in both shape and color. The older, concrete operational child is much more consistent and hence better able to keep track of the task.

The typical concrete-operational child seems like a very mature thinker when compared with a younger child; however, there are still areas of limitation in this period of development. In particular, the child has difficulty thinking in abstract terms. Her thinking is limited to actual or imagined concrete things. And, when compared with an older adolescent, her thinking is less systematic.

## The Formal Operations Stage

The final stage of cognitive development, which begins around puberty, is that of *formal operations.* Adolescents show much more systematic thinking. For instance, when given a number of beakers containing different liquids and asked to determine how they can be mixed together to produce a liquid of a certain color, adolescents do a number of things that younger children do not. First, they can generate all the possible combinations of liquids and often do so in a systematic way. They test one combination at a time and keep track of the results of each one. They are better able to isolate and hold constant all factors except one, and to report on their results accurately. This may be why middle school and high school students seem so much better in science classes at designing and carrying out experiments.

The formal-operational thinker is also able to think more abstractly than the concrete-operational thinker. Adolescents now see reality as one of several possibilities and can imagine other kinds of realities. This new liberation of thought has been described as one of the sources of adolescent idealism and political awakening. Adolescents' awareness of different possibilities opens up for them many different possible paths to the future because they can "think beyond old limits" (Moshman, 2005).

Typically, adolescents are also more adept at logical thinking than are younger children. In part, this has to do with their ability to think abstractly and to reason from arbitrary propositions such as "If all the *X*'s are *Y*'s, and none of the *Y*'s are *Z*'s, then at least some of the *X*'s are not *Z*'s." Adolescents, unlike younger children, are able to understand the idea of *logical necessity* in reasoning. This is the notion that for some arguments, if the premises are true, then the conclusion is guaranteed to be true as well (Moshman, 2005).

Logical thinking also derives from a newly emerging ability Piaget called *reflective abstraction* (Piaget, 1968). Adolescents can, for the first time, acquire new knowledge and understanding simply from thinking about their own thoughts and abstracting from these reflections. By doing so, they may begin to notice inconsistencies in their beliefs. Reflective abstraction is also useful in other realms of thinking, notably those of social and moral thinking. The adolescent is now quite capable of taking the points of view of others and trying to think about issues as others would.

There is much debate over whether all adolescents ever reach the period of formal operations, although Piaget (1972) maintained that they do. However, Piaget did not mean to suggest that even those who do would always display their highest competence. Instead, his idea was that adolescents who acquire formal operations have the ability to think abstractly, systematically, and logically, even if they do not always do so.

Piaget's theory of cognitive development thus describes how thought evolves from simple reflexes to an organized, flexible, logical system of internal mental structures that allow thinking about a wide variety of objects, events, and abstractions. A child at each stage of development has a remarkable set of abilities but often (especially in stages before formal operations) faces several limitations in thinking. The mental structures that allow and organize thought develop slowly through the child's active exploration of the world.

Nancy J. Ashmore

*According to Piaget, hypothetical and deductive reasoning typical of that required for scientific experimentation awaits the development of formal operations.*

## Reactions to Piaget's Theory

Piaget's major writings date from the 1920s, although his fame in the United States was not really established until the early 1960s. Halford (1989) described the 1960s as a period of intense optimism about Piagetian theory in this country as many psychologists and educators sought ways of applying it to problems of designing appropriate educational curricula for children and adolescents of varying ages. However, beginning around the 1970s, enthusiasm for Piaget's ideas began to fade as a number of studies appeared to disconfirm some of the theory's predictions (see Gelman & Baillargeon, 1983, and Halford, 1989, for reviews; see Newcombe, 2002, and Roth, Slone, & Dar, 2000, for other perspectives on Piagetian theory).

Many researchers were concerned about methodological problems in Piaget's studies. His reports of sensorimotor cognitive development, for example, were based on the observation of only three infants, all Piaget's own children (Miller, 2002). Accordingly, it is hard to know how free from bias or overinterpretation Piaget's observations were, although later research has replicated nearly all the phenomena he reported (Ginsburg & Opper, 1988).

In work with older children and adults, Piaget again employed the *clinical method,* often modifying the tasks or questions for each child in response to his or her performance or explanation. Although this approach allows a great deal of flexibility, it also opens the door to various threats to validity, especially the possibility that the experimenter will unconsciously and subtly provide the child with cues or leading questions.

Siegel and Hodkin (1982) pointed out other methodological problems in the tasks Piaget developed. Many seem to require much more than simply the understanding of the concept under investigation. Children in a conservation task, for instance, not only must observe the materials undergoing different transformations and make the correct judgments but also must explain their answers carefully and, in some cases, resist countersuggestions from the experimenter. Siegel and Hodkin argued that when a child is asked the same question several times, to assess the particular cognitive ability with different stimuli, the child may change the answer because he or she believes the adult is asking the question again because the first answer was wrong. Usually adults do not repeat a question when the answer is correct, but only when it is wrong. "[The child's] response vacillation may be interpreted as a sign of unstable cognitive structures, but it may also reflect children's eagerness to provide the answers they think the adult is seeking" (p. 59).

Other investigators and theorists have raised problems with parts of Piaget's theory. Many have agreed that evidence for distinct stages of cognitive development is not strong (Brainerd, 1978; Miller, 2002). A strict interpretation of stage theory would require, for example, that all stage-related abilities appear together, a prediction not well borne out. There is also an arguable lack of evidence for the specific cognitive structures that Piaget described as underlying the different stages (Halford, 1989). Further, a variety of empirical studies have demonstrated a great deal of competence and knowledge among young children for which Piaget's theory has difficulty accounting.

Nonetheless, even his sharpest critics acknowledge a tremendous debt to Piaget. Most investigators admire the wide-ranging scope of the theory and the cleverness Piaget showed in devising tasks to reveal important aspects of children's thinking at different periods in development.

## ■ NON-PIAGETIAN APPROACHES TO COGNITIVE DEVELOPMENT

Many psychologists who study cognitive development appreciate the keen observations that Piaget reported but do not accept his interpretation of their underlying causes. In particular, many believe that cognitive development does not proceed through a series of qualitatively different stages or periods nor that qualitatively different intellectual structures underlie cognition at different periods. Instead, these investigators assert that cognitive skills and abilities emerge or are acquired gradually.

Many of these psychologists use adult models of cognitive processes as a framework within which to understand how children process information. Many take information-processing models, such as those described in earlier chapters, as the starting point for a model of cognitive development. The basic strategy is to discover how information-processing models of adult cognition must be modified to describe and explain the performance of children of different ages and abilities.

As with models of adult cognition, information-processing models of children's cognition use the digital computer as a metaphor for the child's mind. Information presented to the child (either explicitly or implicitly) can be regarded as input. Just as computers have various storage devices (buffers, disks), so too children are assumed to have one or more distinct memory stores. Just as computers retrieve information from their stores, so too children are assumed to be able to access (at least some of) their information and to use it in a number of cognitive tasks, including calculation, classification, identification, and integration. Finally, just as computers write information on disks or on printers or terminal screens, so too do children often produce output of one sort or another: a verbal response, a drawing, a gesture, or some other behavior.

Other psychologists focus on physiological (particularly neurological) and other innate factors that contribute to cognitive development. These psychologists begin with the premise that young infants do not have "blank slates" for minds but instead bring to their cognitive life certain mental structures that are present from birth. Not surprisingly, these psychologists investigate the cognitive competencies of young infants and toddlers, who presumably have had relatively little opportunity for learning cognitive skills.

Still other developmental psychologists are rediscovering another "great theorist" of cognitive development, the Russian psychology Lev Vygotsky (1896–1934). Vygotsky's theory differs from Piaget's mainly in that he sees as inseparable the child and the context in which that child functions. Thus a child's ability to understand the concept of the permanent object, or to conserve number, or to reason systematically cannot be evaluated by focusing on the child alone. Instead, Vygosky held, the environment, both physical and social, within which an activity is carried out must be taken into account.

Vygotsky introduced the concept of the "zone of proximal development" to account for the fact that children can often perform in more advanced ways with guidance or collaboration from an adult (Miller, 2002). When a more competent individual collaborates with a younger, less cognitively mature child, that child's performance is typically enhanced, even if the interaction is informal (Rogoff, 1990). Developmental psychologists in the Vygotskian tradition, therefore, are more apt to investigate children working with adults on everyday tasks. Thus their work falls within the ecological paradigm discussed in Chapter 1.

In this section, we will review a few examples of work that departs from the Piagetian tradition. The examples span a range of types of cognitive tasks, as well as different periods of development. Although they represent only a minute proportion of the possible examples of important research on cognitive development, they provide a sense of the kinds of questions cognitive developmental psychologists ask and how they seek answers.

## Perceptual Development in Infancy

We saw in Chapter 3 that our perceptual activities are crucial to our acquiring information from and about the world around us. It behooves a cognitive psychologist interested in perception, then, to understand how perceptual abilities, skills, and capacities develop. Work with infants conducted by Renee Baillargeon traces the development of perceptual understanding of objects and events across age groups (Baillargeon & Wang, 2002). Consider the ability of infants to understand the concept of physical support; for example, one object can physically support another if (typically) the supporting object is underneath the supported object and if enough of the supported object's surface makes contact with the supporting object.

To make this more concrete, consider Figure 14-3. Imagine showing a research participant one of two events. In the top row, depicting a possible event, a gloved hand pushes one box (with a smiley face) across the top of

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another one. This is called a possible event because in real life it could easily happen. The bottom row depicts an impossible event, one that under normal circumstance could not occur (the experimenters used sleight of hand to make it occur): A box is pushed across the top of a supporting box until only 15% of its bottom surface rests on the supporting box.

What do infants do when they witness these two events? Predictions from Piagetian theory should be that young infants (below 10 months, say), would see both events as equally possible. But they don't. Their facial expressions register surprise (as rated by research assistants who can't see what the infants are looking at). In fact, the results show a developmental pattern quite at odds with Piagetian theory:

> Our results indicate that by 3 months of age, if not before, infants expect the box to fall if it loses all contact with the platform and to remain stable otherwise. At this stage, any contact between the box and the platform is deemed sufficient to ensure the box's stability. At least two developments take place between 3 and 6.5 months of age. First, infants become aware that the locus of contact between the box and the platform must be taken into account when judging the box's stability. Infants initially assume that the box will remain stable if placed either on the top or against the side of the platform. By 4.5 to 5.5 months of age, however, infants come to distinguish between the two types of contact and recognize that only the former ensures support. The second development is that infants begin to appreciate that the amount of contact between the box and the platform affects the box's stability. Initially, infants believe that the box will be stable even if only a small portion (for example, the left 15%) of its bottom surface rests on the platform [see Figure 14-3]. By 6.5 months of age, however, infants expect the box to fall unless a significant portion of its bottom surface lies on the platform. (Baillargeon, 1994, pp. 133–134)

Recall also from Chapter 3 our discussion of the Quinn et al. study (2002), showing that infants aged 3 months do not show evidence of using Gestalt principles of similarity, whereas infants aged 6–7 months do. These authors suggest that different Gestalt principles become functional at different times in an infant's development.

## Toddlers' Acquisition of Syntax

In Chapter 10, we discussed several aspects of language abilities and usage. Each of these aspects shows interesting developmental changes. Most psychologists and linguists who study language development agree on a proposition that at first might seem startling: Children do not *learn* syntax (Chomsky, 1959). That is, the way in which syntax develops from infancy through adolescence is difficult to account for in terms of simple learning mechanisms. One reason is that syntactic development typically occurs in a very short time frame—in only a few years. Further, children undergoing language development hear many different utterances of a language—from parents, siblings, teachers, and others. However, what children appear to acquire are not specific sentences or utterances but rather the underlying rules that govern a particular language. As I hope Chapter 10 convinced you, the rules that govern a language are complex and very difficult to articulate. Thus it is quite unlikely that parents and other adults are teaching these syntactic rules.

Moreover, studies of parents interacting with their children demonstrate that parents rarely correct syntactic errors of children's speech (such as "Yesterday I goed to the playground"), responding instead to the content of what is said (such as "No, honey, yesterday we went to the *zoo*") (Ingram, 1989). These and other arguments cause developmental psychologists to speak of *language acquisition* rather than *language learning*.

Many developmental psychologists studying language acquisition agree with Chomsky's (1957, 1959) assertions that people are born with *language universals;* that is, they are biologically prepared to acquire a human language (as opposed to a computer language or other kind of artificial language). The actual language a child acquires almost certainly is subject to environmental influences: Children born to English speakers invariably acquire English, and those born to parents who speak Hungarian unfailingly acquire that language. Chomsky believes people have a *language acquisition device* (LAD), an inborn set of mechanisms and knowledge that requires only an environmental trigger to be set in motion. The environment controls *which* language(s) is (are) acquired, but the *capacity* to acquire a human language is regarded as innate.

Although children typically begin to use recognizable words at around a year of age, usually not until their second year do they begin producing utterances of more than one word. It is not possible to speak of *syntax* in a toddler's language until he produces multiword utterances, simply because it is not possible to structure a one-word utterance in different ways.

If children's two-word utterances had absolutely no structure, then what we should observe are random pairings of words in a child's vocabulary. In fact, what we observe is quite the opposite: Children's two-word utterances display a considerable amount of regularity. Consider Box 14-1, which presents a number of two-word utterances spoken by my niece, Brandi Lee, when she was about 18 months old. You'll notice that certain words or phrases, such as "Rockabye" or "Oh deah," always occur initially in the utterance; that other words or phrases, such as "down" or "didit," always occur at the end of the utterance; and that certain other words, such as "Dassie," "Mummy," and "Santa," occur either initially or at the end of the utterance.

## **Box 14-1** Sample Two-Word Utterances

Dassie (her word for "Kathie") down. (meaning "Kathie, sit on the floor")
Mummy down. (meaning "Mommy, sit on the floor")
Rockabye baby.
Rockabye turkey.
Rockabye Santa.
Oh deah (dear) Santa.
Oh deah Dassie.
Oh deah Mummy.
Oh deah turtle.
Mummy didit. ("didit" meaning, roughly, to have performed an action)
Dassie didit.
Brannie (her word for "Brandi") didit.

Braine (1963) hypothesized a *pivot grammar* to account for these regularities. Braine argued that children begin to form two-word utterances by first somehow selecting a small set of frequently occurring words in the language they hear. These words are called "pivots." Children's knowledge about pivots includes not only the pronunciation and something about the word's meaning but where in an utterance the pivot should appear. Other words the child uses are called "open" words. Braine argued from data much like that in Box 14-1 that toddlers form "syntactic" rules of the following sort: "Pivot1 + Open" or "Open + Pivot2," where Pivot1 includes all sentence-initial pivots (such as "Oh deah," "Rockabye"), and Pivot2 includes all sentence-final pivots (such as "didit," "down").

Braine's (1963) pivot grammar accounts for some of the regularities apparent in the speech of some children. However, work by other investigators (Bowerman, 1973; Brown, 1973) soon showed that it fails to account for the utterances of all children. Although current consensus is that the grammar is at best incomplete and in many cases incorrect, some investigators have argued that it may provide some useful ideas about how children begin to construct a grammar from the language they hear around them (Ingram, 1989).

Roger Brown (1973) took a different tack in accounting for regularities in children's two-word utterances. Brown asserted that children at the two-word stage are constructing their utterances *not* by following rules of syntax but by using a small set of semantic relations. Table 14-1 presents the semantic relations he proposed. Brown argued that this particular set of relations is an outgrowth of the knowledge toddlers of this age should have about the world. He believed that children at this point in development focus on actions, agents, and objects and are concerned with issues such as where objects are located and when and how they can disappear and reappear. As such, Brown's proposals fit nicely with the Piagetian view of sensorimotor development (Ingram, 1989).

## Table 14-1 Proposed Semantic Relations for Early Grammars

| *Relation* | *Definition and Examples* |
|---|---|
| 1. Nomination | The naming of a referent, without pointing, usually in response to the question “What’s that?” Often indicated with words such as “this,” “that,” “here,” “there.” (Also see “Demonstrative and Entity” below.) |
| 2. Recurrence | The reappearance of a referent already seen, a new instance of a referent class already seen, or an additional quantity of some mass already seen, e.g., “more” or “another” X. |
| 3. Nonexistence | The disappearance of something that was in the visual field, e.g., “no hat,” “allgone egg.” |
| | *Semantic Functions* |
| 4. Agent + Action | The agent is “someone or something, usually but not necessarily animate, which is perceived to have its own motivating force and to cause an action of process” (p. 193), e.g., “Adam go,” “car go,” “Susan off.” |
| 5. Action + Object | The object is “someone or something (usually something, or inanimate) either suffering a change of state or simply receiving the force of an action” (p. 193). |
| 6. Agent + Object | A relation that uses the two definitions above. It can be considered a direction relation without an intervening action. |
| 7. Action + Location | “The place or locus of an action” (p. 194), as in “Tom sat in the chair.” Often marked by forms like “here” and “there.” |
| 8. Entity + Locative | The specification of the location of an entity, i.e., any being or thing with a separate existence. These take a copula in adult English, e.g., “lady home” meaning “the lady is home.” |
| 9. Possessor + Possession | The specification of objects belonging to one person or another, e.g., “mommy chair.” |
| 10. Entity + Attribute | The specification of “some attribute of an entity that could not be known from the class characteristics of the entity alone” (p. 197), e.g., “yellow block,” “little dog.” |
| 11. Demonstrative and Entity | The same as Nomination except that the child points and uses a demonstrative |

**Source:** Ingram (1989, p. 287).

One problem with Brown's approach is that it requires an adult to interpret what the child intended to communicate at the time of the utterance. It makes adults interpret children's language in terms of adult assumptions and beliefs, and it assumes that adults and children use language to refer to events and objects in the world in similar ways. Ingram (1989) pointed out that this assumption can be erroneous.

Much work since the 1970s has attempted to avoid problems in both syntactic and semantic approaches. The complexity and specificity of many of the existing models preclude their being discussed here. However, there is agreement that even from the early days of language use, children's utterances show many regularities. Because many of the regularities observed come from children of very different cultures and language communities, it is further hypothesized that children's language acquisition cannot be the simple result of learning.

## Preschoolers' Use of Memorial Strategies

Many researchers who study the development of memory in children have been struck by the different approaches to memory tasks adopted by younger and older children. A particularly striking difference concerns the use of memorial *strategies,* defined as "deliberate plans and routines called into service for remembering" (Brown, Bransford, Ferrara, & Campione, 1983, p. 85). One important remembering strategy is **rehearsal** of the to-be-remembered material. Rehearsal can involve silent or out-loud repetition and is thought to maintain information in working memory, making it more likely to be stored for longer periods of time (Ornstein & Naus, 1978).

A number of studies (reviewed by Ornstein & Naus, 1978) have repeatedly demonstrated two things. First, younger children (preschoolers and younger elementary school–age children) are less likely to rehearse material than are older children (older elementary school–age children and middle school–age children). Second, when children who do not spontaneously rehearse can be induced to do so, their memory performance often rises to the level of similar-age children who do rehearse spontaneously.

A classic study by Flavell, Beach, and Chinsky (1966) demonstrated the first of these points. The authors worked with children in kindergarten and the second and fifth grades. Each child was shown two sets of seven pictures and was asked to point to the pictures in the same order that the experimenter did. In one condition, the wait was 15 seconds between the time the experimenter finished pointing and the time the child was asked to re-create the order. The children wore special "space helmets" that prevented them from looking at the pictures or seeing the experimenter but allowed the experimenter to observe whether they were verbalizing the items they had to remember (one of the experimenters, trained in lip reading, spent each session watching and listening for such verbalizations). Results were dramatic: Very few of the kindergarten participants showed evidence of rehearsal; a little more than half of the second-graders and almost all the fifth-graders did show such evidence.

A later study (Keeney, Cannizzo, & Flavell, 1967), using a similar procedure, illustrates the second point. These researchers found that 6- and 7-year-old "rehearsers" performed significantly better in recalling information than same-aged "nonrehearsers." When the nonrehearsers were later trained to rehearse, their performance became indistinguishable from that of the initial "rehearsers." However, when left to their own devices the initial "nonrehearsers" abandoned the rehearsal strategy. Brown et al. (1983) believed the use of rehearsal during early childhood is fragile, disappears easily, and occurs under only very limited circumstances (p. 94).

Other research on memory development has shown that children's performance on a memory task is often a function of their preexisting knowledge of, and expertise with, the materials of the memory task. Michelene Chi (1978) demonstrated this in a study with children (in grades 3 through 8) with chess tournament experience and adults with casual experience with chess. When given standard digit-span tasks, the adults tended to outperform the children. However, when the memory task involved recalling positions of chess pieces on boards, the children outperformed the adults. One possible explanation could be that their knowledge allowed the chess-experienced children to notice more relationships between chess pieces (such as "the king's rook is attacking the queen"), facilitating more retrieval cues than were available to the less experienced adults.

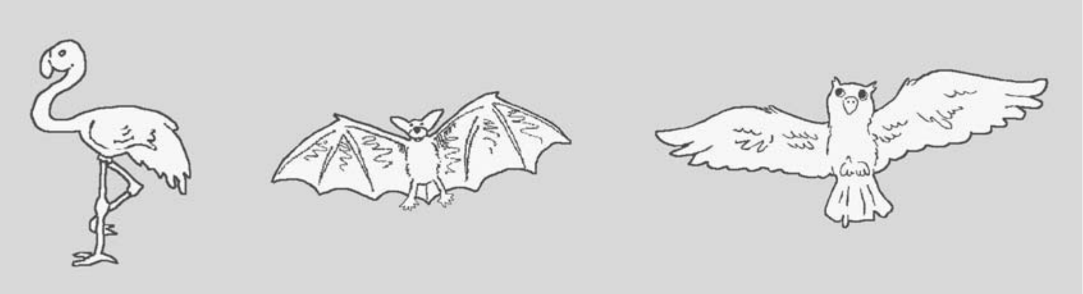
## Conceptual Development in Early Childhood

The subject of how children acquire and structure knowledge is the focus of researchers studying conceptual development. Susan Gelman and her colleagues (Gelman, 1988; Gelman & Markman, 1986) have centered their investigations on the question of how children make inferences about different kinds of things, given that they have some information about the category membership of those things.

Let's examine a specific example. Most of us know that although whales share a number of similarities with various kinds of fish (they swim, they live in water, they are often found in aquariums, they have an overall shape that is fishlike), they are in fact mammals (whales are warm-blooded and bear live young). As adults, we know that a whale must be categorized on the basis of something other than perceived features. The question is, do children know this too? Notice that the Piagetian view would predict that preschool children, being "perceptually bound," would probably perform the classification solely on the basis of how the thing to be classified appears.

**FIGURE 14-4** ■ *Stimuli from Gelman and Markman (1986).*

**SOURCE:** Gelman and Markman (1986, p. 188).



In a series of studies, Gelman and Markman (1986) showed children sets of three pictures like the one shown in Figure 14-4. Each set was carefully constructed so that the third picture *looked* like one of the first two pictures but was really in the same category as the one it did not resemble. Note, for example, that in Figure 14-4 the owl *looks* more like the bat but is really (to a knowledgeable adult) in the same category as the flamingo (both the owl and flamingo are birds; the bat is a mammal). Children were given information about the first two pictures in a set (for example, "This bird's heart has a right aortic arch only" [as the experimenter points to a picture of the flamingo]; "This bat's heart has a left aortic arch only" [as the experimenter points to a picture of the bat]). While looking at the third picture (for example, an owl shaped like the bat), the child was asked to predict what would be true of the owl's heart. Contrary to Piagetian predictions, 4-year-old children based their inferences on category membership rather than on physical appearance (when the two were in conflict) approximately 68% of the time.

In further work, Gelman (1988) investigated the constraints on children's inferences based on category membership. Preschoolers and second-graders first learned presumably new facts about objects (for example, "This apple has pectin inside") and then were asked whether these facts were true of other items of varying similarity (such as other apples, a banana, a stereo). Gelman used two kinds of categories: natural kinds (naturally occurring objects, such as animals, plants, fruits, and other things not constructed by humans) and artifacts (objects constructed by people usually to perform a certain function, such as chairs, tools, computers). Recall from Chapter 8 that adults treat these two kinds of concepts differently. The question was, do children also treat these two kinds of concepts differently, and if they do, at what age do they start to make the distinction?

Gelman (1988) found that children (preschoolers and second-graders) consistently drew the inference that items in the same category shared the new property they had just learned about. For example, on being told that "apples have pectin," all the children were also likely to infer that a banana had pectin, too. They were much less likely to infer that a stereo had pectin. Apparently, then, even preschoolers use their knowledge of category membership to make inferences about what kinds of properties different things might have. It is interesting that second-graders were sensitive to the natural-kind/artifact distinction and drew more inferences with natural-kind concepts. Preschoolers, in contrast, appeared relatively insensitive to the distinction. Gelman believed that this insensitivity resulted from their relative lack of deep knowledge about the objects being talked about.

## The Development of Reasoning Abilities in Middle and Late Childhood

The final set of examples illustrating information-processing models of cognitive development describes the development of reasoning abilities. A classic study by Osherson and Markman (1975) showed that first-, second-, and third-graders had apparent difficulty distinguishing between statements that were empirically true or false (that is, true in fact) and those that were logically true or false (that is, true by necessity or definition). The experimenter showed children, adolescents, and adults small plastic poker chips in assorted solid colors. Children were told that the experimenter would be saying some things about the chips and that the children should indicate after each statement if it was true, false, or they "couldn't tell." Some of the statements were made about chips held visibly in the experimenter's open hand. Other, similar statements were made about chips hidden in the experimenter's closed hand. Among the statements used were logical *tautologies* (statements true by definition)—for example, "Either the chip in my hand is yellow, or it is not yellow"; logical *contradictions* (statements false by definition)—for example, "The chip in my hand is white, and it is not white"; and statements that were neither true nor false by definition but depended on the color of the chip.

First-, second-, third-, and even sixth-graders did not respond correctly to tautologies and contradictions, especially in the hidden condition. They tended to believe, for example, that a statement such as "Either the chip in my hand is blue, or it is not blue" cannot be assessed unless the chip is visible. Tenth-graders and adults, in contrast, were much more likely to respond that even when the chip couldn't be seen, if the statement was a tautology or contradiction the statement about it could be evaluated on the basis of form. These results were consistent with Piaget's assertion that logical reasoning, particularly abstract, hypothetical reasoning, awaits the attainment of formal operations in adolescence.

A later study by Hawkins, Pea, Glick, and Scribner (1984) painted a different picture. These authors gave 4- and 5-year-olds a number of verbal syllogisms, such as "Pogs wear blue boots. Tom is a pog. Does Tom wear blue boots?" The syllogisms required logical reasoning. Contrary to expectation, the preschoolers could correctly answer many of the syllogisms and provide appropriate justifications for their answers, especially if the problems were about make-believe animals, as in the example above. The authors believed these syllogisms in particular prevented the children from using their preexisting knowledge of animals (they had probably not had previous knowledge of, or experience with, a pog).

With other syllogisms that were about real animals or objects, the children performed noticeably worse, especially when the premises in the problem were incongruent with the children's preexisting world knowledge (for example, "Glasses bounce when they fall. Everything that bounces is made of rubber. Are glasses made of rubber?"). This result implies that although some ability to reason logically might begin in early childhood, much is undeveloped or unreliable, at least until early adolescence, and maybe all through adulthood (see the discussion on adults' reasoning abilities in Chapter 12).

Another study, by Moshman and Franks (1986), supports this view. They gave children (fourth- and seventh-graders) a more stringent test of logical reasoning competence. The children were presented with sets of three cards. On each card was typed an argument that was either (a) empirically true or false or (b) logically *valid* (the conclusion followed necessarily from the premises; see Chapter 12) or invalid. Participants were asked to sort the cards in as many ways as they could. In some of the studies, they were given definitions of the concepts of validity and were prompted to sort on this basis. However, even when specifically asked to do so, fourth-graders had difficulty sorting on the basis of validity (as opposed to, say, truth of the conclusion or format of the argument). Moshman and Franks interpreted these results as indicating that even when children can draw logically valid conclusions, they don't fully appreciate the idea of validity before age 12 or so.

My collaborators and I (Galotti, Komatsu, & Voelz, 1997) followed up on this line of work, looking to see when children recognized the difference between a deductive and an inductive inference. The following two versions illustrate these two types of inference: (1) "All wortoids have three thumbs. Hewzie is a wortoid. Does Hewzie have three thumbs?" versus (2) "Hewzie is a wortoid. Hewzie has three thumbs. Do all wortoids have three thumbs?" Most adolescents and adults see a distinction between the first problem (which calls for a deductive inference) and the second (which calls for an inductive inference). The former can be made with much greater confidence (in fact, with certainty); the latter, with only some (however strong) degree of probability. Our studies showed that until fourth grade, children did not consistently and clearly articulate the inductive/deductive distinction; however, by about second grade, they showed an implicit understanding of the distinction, answering more quickly and more confidently when asked to draw deductive inferences.

This examination of recent work in the non-Piagetian traditions of cognitive development has yielded narrower and more specific descriptions of what actually develops. Typically, instead of focusing on general and widespread cognitive achievements, researchers in these traditions offer accounts that are more specific to the particular tasks being used. Thus an account of how reasoning ability develops may show little resemblance to an account of how children acquire and organize new information into concepts. Researchers such as those whose work has been described, however, see this narrowness of scope as positive. By attending to specific tasks and domains, they believe a clearer and more accurate picture will emerge of what children know and can do.

Some developmentalists see a large hole left by the demise of grand theories such as Piaget's (Bjorklund, 1997). They call for us to examine children's performance on various cognitive tasks in the context of their everyday experiences and to look at the evolutionary "advantages" of what may appear to adults to be "failures." For example, Bjorklund and Green (1992) argued that preschoolers' unrealistic optimism about their own abilities, frequently taken as an indication of their lack of realistic self-judgment, has some beneficial side effects. Children who think their abilities in some domain are terrific will work longer and harder at practicing their skills in that domain. My son Timmy gave many daily examples when he was a 5-year-old. Convinced his basketball skills were "awesome," he regularly spent many tireless sessions shooting "hoops," despite a low success rate. As an adult, my own skills at estimating my basketball skill are much better. (Perhaps as a result, I spend as little time as possible practicing my free throws.)

## ■ SOME POST-PIAGETIAN ANSWERS TO THE QUESTION "WHAT DEVELOPS?"

Recall from our discussion earlier that Piagetian theory describes cognitive development as the acquisition of progressively more sophisticated mental structures. Researchers in other traditions do not necessarily believe that children at different ages possess qualitatively different mental structures. These researchers instead provide a variety of answers to the question "How do children develop cognitively?" Here we will review some of the most common answers.

### Neurological Maturation

One factor to which cognitive and cognitive developmental psychologists are paying increasing attention is that of neurological, or brain, development.

Although many neurons or nerve cells in the brain emerge during gestation, the brain continues to grow and develop after birth, especially in the first four years (Nowakowski, 1987). Early exposure to stimuli helps to develop a normal level of interconnections among neurons, such that a more complex network of nerve cells is formed. The network allows for the efficient transmission of a great deal of information.

Do neurological developments bear directly on cognitive developments? Goldman-Rakic (1987) described research with monkeys suggesting that the age at which infant monkeys can perform certain cognitive tasks (such as a Piagetian object permanence task) coincides with the peak of the development of neuronal connections in an area of the brain known as the *prefrontal cortex*.

Adele Diamond (1991) has extended this line of work, using a classic object permanence task in which an infant, having previously seen an object hidden in location A, watches it hidden in location B, but continues to look for the hidden object in location A instead of B. Diamond compared older (7–12 months) infants' ability on the "A, not B" object permanence task to the development of the frontal cortex. This area of the brain has been shown to undergo tremendous growth, both in density of synapses and in myelination of axons. Diamond's work has shown that improved performance on the "A, not B" task correlates with age (and therefore with frontal-lobe development) in infancy. In her work with monkeys with frontal-lobe lesions, she has produced monkeys with specific neurological deficits who show the same pattern of behavior on the "A, not B" task as do infants of different ages.

Diamond (1991) believed that the frontal cortex underlies cognitive performance both in the ability to integrate information over time and space *and* in the ability to inhibit strong response tendencies. The infant searching for an object in location A (where it has been previously hidden) instead of in B (where it was just hidden) must keep track of the information that the hiding place has changed and also stop himself from making the same behavioral response (reaching toward A) that was previously successful.

More recent work involving brain imaging techniques paints the following picture: With development, the brain becomes more fine-tuned and organized. Brain regions associated with so-called "basic" functions, such as sensation and motor behavior, develop first, in line with Piagetian tenets. Association areas—brain regions that facilitate integration of information—develop a little more slowly. Areas involved in top-down control of behavior, such as the frontal and prefrontal cortex, are the last to develop (Casey, Tottenham, Listen, & Durston, 2005). Moreover, as the individual develops and has certain experiences, certain synaptic connections between neurons in the brain are strengthened, while other, unused ones, are pruned. This pruning results in more efficient neural circuits, but ones that become increasingly specialized and unique to the individual. Kuhn (2006) speculates that this brain reorganization might account for why, during adolescence, individual differences in performance become more and more common. Although it's possible to talk about the cognitive abilities of a typical 6-month-old, by the time children reach adolescence, there are much wider variations in performance—some adolescents can perform like adults on some tasks, while others cannot. One important factor in this variation, Kuhn believes, stems from the experiences the adolescents engage in, which in turn direct the maintenance or pruning of different neural circuits.

The issue of neurological underpinnings of cognitive performance is at the cutting edge of research at the moment. Whether certain cognitive tasks require a certain level of neurological development and the role of environmental experience in neurological functioning and development are matters that will surely be addressed in the coming decade.

## Working-Memory Capacity and Processing Speed

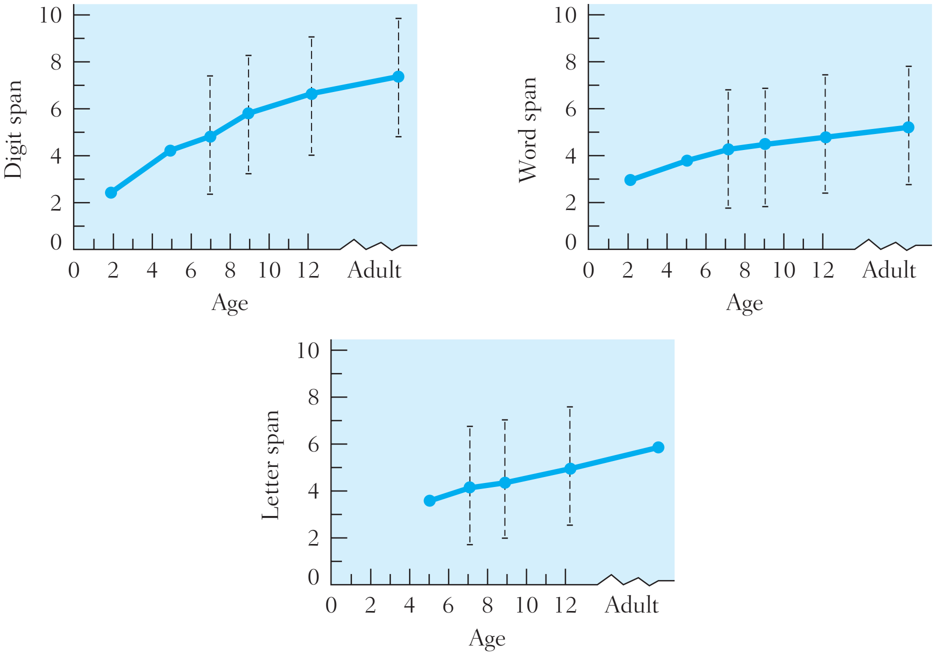
Our review of memory in Chapters 5 and 6 suggested that working memory is an essential ingredient of many cognitive tasks. Recall that working memory is the system in which currently active information is stored and manipulated. It stands to reason, then, that the larger the working-memory capacity, the more complex are the cognitive tasks of which a person is capable. Researchers such as Pascual-Leone (1970) and Gathercole and her colleagues (Gathercole & Pickering, 2000) have tried to measure the amount of "mental space" children seem to have available to perform cognitive tasks. These authors report increases in this capacity with age.

Some of the research has involved estimation of *memory span,* done by giving children lists of items, such as numbers, letters, or words, and asking the children to repeat them. The memory span is thus the number of items that a child of a particular age can reliably reproduce. Figure 14-5 displays data from several studies suggesting that memory span increases with age.

Some proposals assert that working-memory span is constrained by how quickly information deteriorates from the mental workspace (Hitch, Towse, & Hutton, 2001). Still other researchers have argued that what develops is not working-memory capacity per se but the speed and/or efficiency with which information is processed (Case, 1978; Dempster, 1981). For example, children at different ages have been shown to differ widely in the speed with which they can name items presented to them, rotate mental images, or search through a visual display (Kail, 1986, 1988). Adults and older children typically perform all these tasks faster than younger children do. Presumably, all these tasks are carried out in working memory. When one task takes longer to carry out than another, it may reflect the expenditure of more "mental effort." If mental effort is limited, as information-processing theories typically assume, then tasks that require more mental effort will leave fewer cognitive

**FIGURE 14-5** ■ *Developmental differences in digit span, word span, and letter span.*

**SOURCE:** Dempster (1981, pp. 66–68).



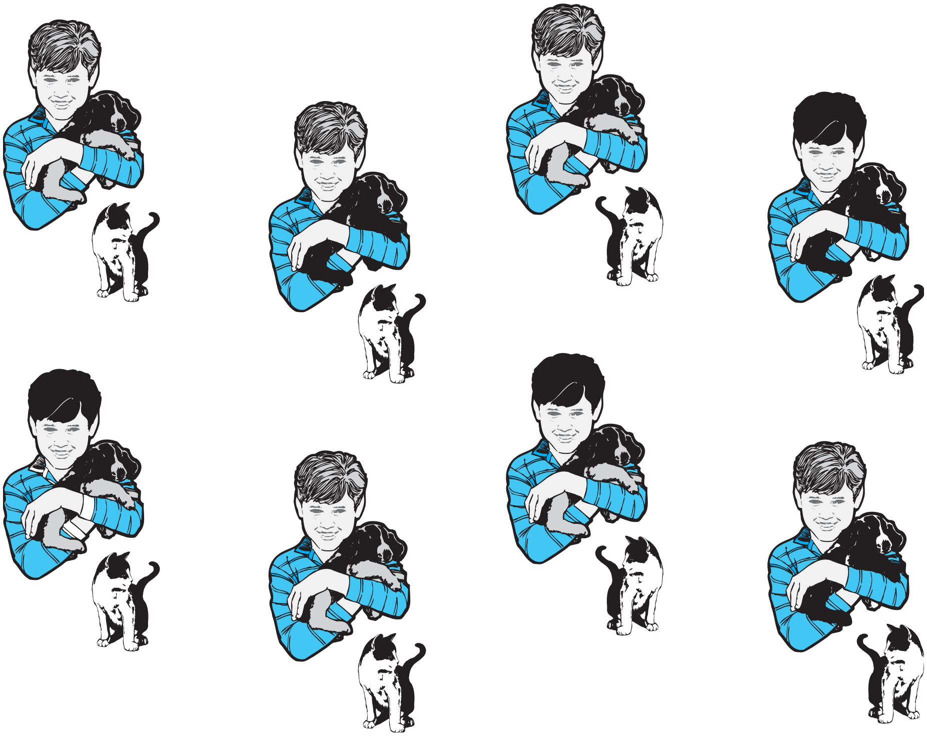
resources available for other processing. This in turn could explain the generally poorer cognitive performance of younger children relative to older children and adults: The younger the processor, the more mental effort is required for a given task. The question of how working-memory capacity and efficiency change with development is still a current research question (see Cowan, Elliott, Saults, Nugent, Bomb, & Hismjatullina, 2006, for a detailed example of research in this area).

## Attention and Perceptual Encoding

Ask any parent or teacher: Younger children have shorter attention spans than older ones. Because of this, they often spend less time exploring the information available to them from the environment. Preschoolers, in particular, often respond to complex cognitive tasks *impulsively*—that is, quickly and with many errors (Kogan, 1983). Perhaps related to this, younger children make fewer discriminations between similar objects than do older children (Gibson & Spelke, 1983).

You can see a good example of this phenomenon if you look at the comics sections of many Sunday newspapers. Some run a puzzle activity that calls for the child to examine two very similar pictures and to find ten things that differ between them. The two pictures are usually visually complex, with a great number of objects and/or people and a great deal of detail and elaboration of each object. The differences tend to be in the details. For example, one picture might depict a girl with a spotted bow in her hair; another might show the same girl, in the same pose, with the same clothes except for a striped bow. Figure 14-6 gives an example of such a puzzle. Preschoolers and children in early elementary school typically find these puzzles much more challenging than do older children or adolescents. In part, this has to do with the amount of time they spend looking back and forth between the two pictures. Another part of the explanation, predicted by perceptual learning theory (Gibson, 1969), seems to be that younger children notice fewer differences in the first place.

**FIGURE 14-6** ■ *Find the two pictures that match exactly.*



Kemler (1983) has extended this idea, arguing that with development, children shift from a **holistic** approach to processing information to a more **analytic** one. By these terms Kemler means that younger children approach information globally and pay attention to the overall similarities between and among objects. For example, given a red triangle, an orange diamond, and a green triangle and asked to "put together the items that belong together," younger children tend to sort the red triangle and orange diamond together, because overall, these two objects are more similar to each other than either is to the green triangle. In contrast, older children and adults pay attention to particular parts or aspects of information. Given the same sorting task, adults would be likely to classify the red and the green triangles together, because they both share the dimension of shape. Children have also been shown to have difficulty focusing their attention.

In one study, Strutt, Anderson, and Well (1975) asked children and adults to sort as quickly as possible a deck of cards showing various geometric figures. Some cards showed figures that differed only in the relevant dimension—for example, only circles and squares when the child was asked to sort on the basis of shape. Other cards included figures that differed on both the relevant dimension and other, irrelevant dimensions—for example, the presence of a line or star either above or below the picture. The presence of irrelevant information did not affect the speed of sorting for adults. However, it did slow down sorting among 6-, 9-, and 12-year-olds; the younger the child, the greater the interference. This answer to the question "What develops?" implies that younger children approach cognitive tasks differently from older children both perceptually and attentionally. Younger children encode and pay attention to different aspects of information from those aspects older children and adults emphasize. As a consequence, their information processing differs because it begins with different input.

## The Knowledge Base and Knowledge Structures

Some developmental psychologists working in the information-processing tradition regard the acquisition of general knowledge and expertise as a crucial aspect of cognitive development. Studies of adults show that people differ in some cognitive processes as a function of level of expertise with the materials used in the task. For example, Chase and Simon (1973) showed a chess master (a certified "expert"), an experienced chess player, and a chess novice different chessboards with the pieces arranged in various ways. The task was to look at a particular board for 5 seconds and then, after the board was removed from view, to reconstruct the placement of the pieces on a second, empty chessboard.

The investigators found that when the first chessboards depicted actual games (that is, the pieces were arranged in ways that might actually occur during a game), the master and experienced player performed much better than the novice in the number of pieces they could correctly place. However, when the pieces were displayed in random configurations, the chess master performed no better than the novice or the experienced player. Chase and Simon (1973) concluded that experts extract more information than do novices when the information being presented is of the type for which their expertise is relevant. Said another way, expertise helps a person acquire and organize information much more efficiently, thus leading to better overall performance when the information pertains to her area of expertise. Notice that this explanation fits well with the findings of Chi with child chess experts, discussed earlier.

Chi and Koeske (1983) carried out a related study with a single 4½-year-old fancier of dinosaurs. The investigators first queried the child about his familiarity with and knowledge about different kinds of dinosaurs and then drew up two lists: 20 dinosaurs that the child knew relatively more about and 20 that the child knew relatively less about. On three different occasions, the child was presented with each list, at the rate of 1 dinosaur name every 3 seconds, and was then asked to recall the list. The child recalled significantly more of the "familiar" dinosaurs (about 9 out of 20) than the "unfamiliar" ones (about 4 out of 20).

Nancy J. Ashmore

*Chi's work suggests that in domains where children have expertise, such as knowledge of toys, children demonstrate better memorial ability.*

Chi and Koeske (1983) argued from these and other results that part of the reason why children typically perform so poorly on memory (and presumably other cognitive) tasks may be their relative lack of knowledge or expertise regarding the information used in the tasks. Given the opportunity to perform the same tasks with materials they know well, their performance improves dramatically. Presumably, familiar materials require less cognitive effort to encode, retrieve relevant information about, notice novel features of, and so on.

Other work, by Katherine Nelson and her colleagues, looked in a slightly different way at how children store and organize knowledge, particularly knowledge about events (Nelson, 1986). The primary method here is to ask children to describe their knowledge of familiar routines, such as "What happens when you go to day care?" or "Tell me what happens when you make cookies." In response to the latter request, Nelson and Gruendel (1981) obtained a variety of responses from children of different ages, ranging from "Well, you bake them and eat them" (a 3-year-old) to "First you need a bowl, a bowl, and you need about two eggs and chocolate chips and an egg beater! And then you gotta crack the egg open and put it in a bowl and ya gotta get the chips and mix it together. And put it in a stove for about 5 or 10 minutes, and then you have cookies. Then ya eat them!" (a child of 8 years, 8 months) (p. 135).

First, clearly even 3-year-olds have some knowledge of this event. Nelson described the organization of this knowledge in terms of *scripts,* or *generalized event representations* (GERs). From Chapter 6, you may remember that scripts contain information organized temporally—that is, by the time in which each thing occurs in an event. Notice how the children use temporal links from one step to another—for example, "*First* you do X, *then* Y, and *after that* you do Z." One trend that appears with development is that the scripts become longer and more elaborate. Fivush and Slackman (1986) also showed that as children become more familiar with an event (for example, if the event is "going to kindergarten" and children are tested repeatedly as the school year goes on), their scripts also become more complex, specifying more conditional information, such as "If it's raining, we play indoors." Children's organization becomes more hierarchical as they specify more options or choices for different activities (for example, "I can play house, or I can draw, or I can read a book, until circle time"). Their organization also becomes more abstract; when describing their script they mention fewer details specific to a certain day's activity.

Nelson (1986) argued that scripts help to support many cognitive activities, including comprehension, memory, and conversation. Scripts and GERs are said to provide the child with a "cognitive context" with which to interpret actions, events, and people in a situation. Especially because younger children appear to perform at their cognitive best only in certain contexts, it is important to learn which aspects of the context help or hinder them. Nelson believed that "the observed difference between situations where children perform well or poorly is that between those for which children have established a relevant GER and those for which they have not" (p. 16).

## Strategies

When confronted with a complex cognitive task, adults often develop certain systematic approaches to it that help them to manage the task requirements more efficiently. Such approaches are called *strategies.* For example, when studying for an upcoming examination, many college students review their lecture notes, develop outlines of each course reading, and consult with the instructor about material they find unclear. All these are strategies.

The role of strategies in cognitive development has already been alluded to in the discussion of Flavell's classic work on rehearsal strategies (Flavell et al., 1966; Keeney et al., 1967). Recall that their work showed that younger children were less likely spontaneously to adopt a rehearsal strategy in a memory task but could be taught to use one. However, when not required to use the strategy, most younger children abandoned it. Keeney et al. (1967) argued that nonrehearsers suffer from a *production deficiency*—that is, a tendency not to produce the appropriate strategy for a given task. Although the children were capable of using the rehearsal strategy, they did not do so spontaneously and did not use it when given the option not to.

Why? Some have answered that strategies require mental effort and younger children may simply find it much harder to use a strategy than older children (Howe & O'Sullivan, 1990). Perhaps with increasing cognitive development (for example, greater neurological maturation, more working-memory capacity, larger knowledge bases, or some other factor or combination of factors), the mental effort required to execute a strategy declines, making it a more useful addition to the cognitive repertoire.

This explanation is consistent with other research findings on strategy use, in which older children have been shown to be more flexible and better able to tailor their choice of which strategy to use on a task that allows for several different strategies (Miller, Haynes, DeMarie-Dreblow, & Woody-Ramsey, 1986). Siegler and Jenkins (1989), reviewing work on children's arithmetic strategies, also pointed out that although children and adults at almost any age usually have a variety of strategies they could use, with age and experience comes the likelihood of using more sophisticated strategies (that presumably demand more mental effort for execution). In any case, it is clear that strategies facilitate the processing of information and that people who use better strategies (for whatever reason) often have better cognitive performance. Younger children do not show the same use of strategies that older children and adults do and thus are at a disadvantage on many cognitive tasks.

Britt Erlanson/Getty Images

*Research shows that as children gain experience with arithmetic, they begin to adopt more sophisticated strategies, which enables better performance.*

## Metacognition

Given the same cognitive task, older children are usually better than younger children at evaluating its complexity and monitoring their own performance. For example, in a memory study conducted by Flavell, Friedrichs, and Hoyt (1970), preschool and elementary school children were given a set of items to study until they were sure they could remember them. Older children were better able to judge when they had studied adequately and to predict how many items they would be able to recall.

Flavell (1985) described this as one aspect of **metacognition,** defined broadly as "any knowledge or cognitive activity that takes as its object, or regulates, any aspect of any cognitive enterprise" (p. 104). The general idea is that metacognition consists of "cognition about one's own cognition." It includes *metacognitive knowledge*—that is, knowledge about one's own cognitive abilities and limitations. You are probably pretty accurate, for example, at describing your memorial abilities, your attention span, and the relative depth and breadth of your knowledge of a particular domain (such as football, cognitive psychology, or trivia). You know your own areas of strength and weakness, you know what strategies work best for you, and you know when to use them.

Younger children are less knowledgeable about their own abilities and are typically much too optimistic about how well, how easily, or how fast they can perform on most cognitive tasks.

Metacognition also includes *metacognitive experiences,* things that happen to you that pertain to your knowledge or understanding of your own cognitive processes. For example, experiences of uncertainty or doubt and periods of deep reflection over your performance, decision making, or values are all examples of metacognitive experiences. Flavell's (1985) idea is that older children and adults are better able to recognize, and realize the significance of, different metacognitive experiences.

Metacognitive knowledge and regulation are obviously important in many cognitive tasks. Part of the reason why younger children perform more poorly on cognitive tasks may be that they do not have the metacognitive knowledge about what the tasks demand. That is, they do not know how to judge the difficulty of the task and thus do not approach it with the necessary procedures or other tools. It may also be that younger children have less metacognitive control over their processing of information (Brown et al., 1983). Markman (1979), for instance, showed that third-graders were less able than sixth-graders to report inconsistencies or contradictions in passages they read, even when prompted to read the passages aloud. In a later study (Markman & Gorin, 1981), 8- and 10-year-old children who were explicitly told to look for inconsistencies in passages were able to do so. The general conclusion from these studies is that children do not spontaneously monitor their cognitive performance while reading but can be induced to do so. However, unless the conditions are optimal, children, especially younger children, may fail to notice when cognitive processing goes awry.

Cognitive developmental psychologists have more recently turned their attention to a related area of investigation: children's theories of mind (for example, Butterworth, Harris, Leslie, & Wellman, 1991; Flavell, 1999; Perner, Lang, & Kloo, 2002). The term *theory of mind* is meant to capture the intuition that adults treat one another as cognitive beings, making certain assumptions about each other's perceptual, attentional, memorial, language, and thinking skills, as well as their desires and intentions—in other words, their mental states. This set of assumptions is collectively referred to as a *theory of mind.*

One common task used to investigate children's (usually preschool children's) theory of mind is the so-called *false belief* task. For example, children might be told a story about a boy who puts a toy in a box and leaves the room. While he is away, his sister enters the room, takes the toy out of the box, plays with it, and puts it away in a different location. Children are then asked where the *boy* will think the toy is. In other words, can the children disentangle *their* own state of knowledge about the toy from the state of knowledge/belief of someone who lacks their information? Consistent with Piagetian theory, this ability develops slowly over the preschool period (Jenkins & Astington, 1996). Theory of mind appears related generally to language ability, although not to memory ability. Preschoolers apparently have much to learn about the mental states of others (for example, what others might be thinking, wanting, remembering) as well as their own mental states. Work by Flavell, Green, Flavell, and Grossman (1997) even demonstrates that 4-year-olds have difficulty knowing when they are engaging in inner speech to themselves!

We have reviewed a great deal of material on cognitive development. Yet given the number of active investigations in the field, we have barely scratched the surface of all the important available information.

Cognitive developmental psychologists are also challenged by the question "What causes development?" In particular, there is ongoing and lively debate over how much of cognitive development is caused by physical factors, such as genetics or maturation, and how much can be attributed to environmental forces, such as schooling or the opportunity for practice. A current focus within the field is to identify the factors that cause, hinder, or facilitate cognitive development.

Because this chapter focuses on infants, children, and adolescents, you might be left with the impression that cognition in adulthood does not change and/or is the same for all adults. This impression is false, as we will see in Chapter 15. Adults as well as children differ in their amount of expertise, as well as in the ways they characteristically carry out cognitive tasks. Moreover, recent work in cognition and aging (to be reviewed in the next chapter) also suggests that changes in cognition as a function of age do not cease at puberty.

## SUMMARY

1. Cognitive performance varies for children of different ages. In other words, children do not perform in the same way as adults on many cognitive tasks, including tasks of perception, memory, categorization, problem solving, and reasoning. Generally speaking, the younger the child, the greater the difference between his or her performance and that of a typical adult. Because children do differ from adults, it takes cleverness and care to design informative studies that can help explain how cognitive development occurs and can be facilitated.
2. The description of how children differ from adults or how younger and older children differ from one another is still a matter of debate. Some psychologists, especially those working in a Piagetian tradition, believe that the best description of cognitive development must emphasize qualitative differences among people of various developmental levels and underlying mental structures.

3. Piaget proposed a stage theory, which describes development as consisting of qualitatively different periods of development. Stage theories presume a fixed order to the progression of stages and typically assume that the proposed stages are universal across cultures.
4. Piaget divided cognitive development into four basic stages. The first, the sensorimotor period, is one in which infants gain new knowledge through their sensory and motor experiences and lack the capacity for mental representation. At around 18 months to 2 years, toddlers enter the preoperational stage of cognitive development, during which they acquire representational and symbolic abilities, language, and the capacity for imagination and fantasy play. At the same time, their cognitive abilities are constrained by their egocentrism, their centering on one dimension, and their irreversible thinking.
5. Piaget asserted that children of elementary school age (roughly 5 to 11 years) become concrete-operational thinkers; they can take account of more than one aspect of a situation, conserve quantity, think reversibly, and classify consistently. Finally, in adolescence children acquire formal operations—the ability to think systematically, abstractly, and hypothetically.
6. Researchers working outside the Piagetian tradition focus on changes in the basic cognitive capacities (such as memory capacity, attention span, knowledge base) and in the ways in which information is organized. They consider genetic and maturational underpinnings of cognitive functioning and also the developmental changes that affect the approaches that children of different ages take toward cognitive tasks. Unlike Piagetian researchers, many non-Piagetian theorists reject the idea of different qualitative stages of cognitive development. Instead, they regard cognitive development as the gradual acquisition and organization of capacities, strategies, and knowledge that allow for more efficient cognitive performance.

## REVIEW QUESTIONS

1. What are the major assumptions of stage theories of development?
2. Explain how, in Piagetian theory, cognitive structures adapt during the course of development.
3. Piaget asserts that children at different stages of development differ from one another cognitively in qualitatively different ways. Illustrate this assertion with some specific examples.
4. Describe the major features of preoperational thought, according to Piaget.
5. Evaluate the implications of Baillargeon's research on perceptual development in infancy.

6. Why do most cognitive developmental psychologists distinguish between the terms *language learning* and *language acquisition*? What sorts of arguments are used in support of this distinction?
7. In what ways does research on the development of reasoning abilities in middle and late childhood support or run counter to Piagetian predictions?
8. Contrast two mechanisms that have been proposed to account for cognitive development.

## KEY TERMS

analytic processing
holistic processing
metacognition
rehearsal
stage theories of cognitive development

## CogLab DEMONSTRATIONS

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

## WEB RESOURCES

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# CHAPTER 15

# Individual, Aging, and Gender Differences in Cognition

**Individual Differences in Cognition**
    Ability Differences
    Cognitive Styles
    Expert/Novice Differences

**The Effects of Aging on Cognition**

**Gender Differences in Cognition**
    Gender Differences in Skills and Abilities
    Gender Differences in Learning and Cognitive Styles

So far, we have been assuming that cognitive development proceeds in pretty much the same way for everyone. In the previous chapter, of course, we saw that children often don't approach cognitive tasks exactly the way adults do, but we made the assumption that with time, maturity, and perhaps education, they come to do so. In effect, we've been ignoring what psychologists call **individual differences,** stable patterns of performance that differ qualitatively and/or quantitatively across individuals.

In Chapter 16, we will consider differences in cognition as a function of one's culture. Here, we will consider some other sources of individual differences—differences in cognitive abilities, concentrating on intelligence, and differences in cognitive styles of approaching particular tasks. We will also consider gender differences in cognition: stable differences in cognition or cognitive processing of information that vary as a function of one's biological sex and psychological attitudes associated with one's sex.

Why are cognitive psychologists interested in individual or gender differences in cognition? Simply stated, if people vary systematically in the way they approach cognitive tasks, then psychologists cannot speak of "the" way cognition works. To present only one approach if in fact there are several is to ignore human diversity and to assume that only one way exists for carrying out a task. Researchers interested in individual and gender differences try to explain why some people seem to consistently outperform others on cognitive tasks and why some people feel more comfortable with certain cognitive tasks than with others.

## ■ INDIVIDUAL DIFFERENCES IN COGNITION

The term *individual difference* is meant to capture the intuition that different people can approach the same task in different ways. Psychologists who study personality traits are among those most likely to be interested in individual differences. The individual differences of interest to cognitive psychologists are generally of two distinct types: individual differences in abilities (that is, the capacities to carry out cognitive tasks) and individual differences in style (that is, the characteristic manner in which one approaches cognitive tasks).

### Ability Differences

Many psychologists equate cognitive abilities with **intelligence.** Hunt (1986), for example, has stated that "'intelligence' is solely a shorthand term for the variation in competence on cognitive tasks that is statistically associated with personal variables. . . . Intelligence is used as a collective term for 'demonstrated individual differences in mental competence'" (p. 102). Other psychologists do not make this equation, but most agree that people do vary in their intellectual (as well as several other important) abilities. Psychologists disagree over whether the best way to describe this variation is in terms of one general mental ability (called intelligence) or in terms of more numerous and varied intellectual abilities (Sternberg & Detterman, 1986).

Even psychologists who accept the idea of a general mental ability called intelligence debate just what the ability is. Some see it in terms of a capacity to learn efficiently; others, in terms of a capacity to adapt to the environment. Other conceptions of intelligence include viewing it as mental speed, mental energy, or mental organization (Gardner, 1983, 1999; Sternberg, 1986a). Many psychologists who study intelligence have looked at stable individual differences among various cognitive capacities to describe more general differences in people's performance on broader intellectual tasks.

There are many lively and ongoing debates over what the set of cognitive capacities are; one representative list, described by Horn (1989), follows (note that the list below does not purport to represent totally independent skills or capacities):

- Verbal comprehension: understand words, sentences, paragraphs
- Sensitivity to problems: suggest ways to solve problems
- Syllogistic reasoning: draw conclusions from premises
- Number facility: compute arithmetic operations
- Induction: indicate a principle of relations
- General reasoning: find solutions for algebraic problems
- Associative memory: recall associated element when given another element
- Span memory: immediately recall a set of elements after one presentation
- Associational fluency: produce words similar in meaning to a given word
- Expressional fluency: produce different ways of saying the same thing
- Spontaneous flexibility: produce diverse functions and classifications for an object
- Perceptual speed: find instances of a pattern under speeded conditions
- Visualization: mentally manipulate forms to visualize how they would look
- Spatial orientation: visually imagine parts out of place and put them in place
- Length estimation: estimate lengths or distances between points

The claim here is that people (both adults and children) can vary in many ways. Just as we all vary in athletic prowess, musical talent, or sense of humor, so too can we vary in intellectual or cognitive ways: in terms of memory capacity, attention span, concentration, and so on. These differences, in turn, can cause differences in the ways in which we approach and perform cognitive tasks.

A study by Keating and Bobbitt (1978) illustrates this point. These investigators conducted three experiments with both high-mental-ability (as assessed by a nonverbal intelligence test) and average-mental-ability third-, seventh-, and eleventh-graders. The experiments were all based on cognitive tasks previously used with adults, including the memory-scanning experiments described in Chapter 5. The authors found that when they controlled for the effects of age (and presumably, therefore, for developmental level), ability differences were still apparent, especially on the more complicated cognitive tasks. Figure 15-1, for instance, shows results of the memory-scanning task as a function of set size, age, and ability level. Note that older children had faster reaction times than younger children and that within each age group, high-ability students were faster than average-ability students.

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Keating and Bobbitt (1978) believed that both age and ability differences result from the efficiency with which basic cognitive processes (such as encoding and memory scanning) are carried out. They asserted that high-ability children (and adults) simply acquire, store, and manipulate basic information more rapidly and efficiently than do their same-age, normal-ability peers. The same kinds of speed and efficiency differences also occur between older and younger children.

A related, and classic, study by Hunt, Lunneborg, and Lewis (1975) examined a specific hypothesized component of intelligence, verbal ability. These authors examined two groups of undergraduate students: those with relatively high scores on a verbal subtest of a standardized test similar to the College Board's SAT and those with relatively low scores on the same test. (The authors pointed out the latter group had scores that would be considered "average" in the general population.) The aim of the study was to investigate whether differences in verbal ability, as reflected in standardized scores, might be explained by differences in basic cognitive skills.

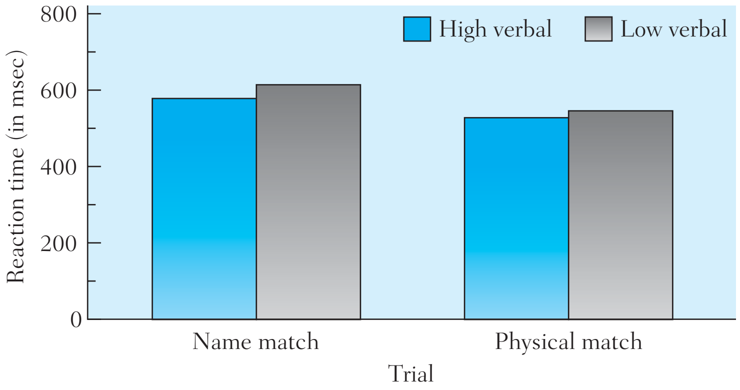
One of the many cognitive tasks they assigned to the participants was based on a perceptual matching task created by Posner, Boies, Eichelman, and Taylor (1969). In this task, participants are presented with two letters—for example, A and B, or A and a, or A and A. They are to decide, as quickly as possible, whether the two letters presented are the same. In one condition (called "physical match"), they are instructed to respond yes only when the two stimuli match exactly—"A A" or "a a," for example, but not "A a." In another condition (called "name match"), participants are instructed to respond yes if the two stimuli refer to the same letter, so that "A A," "a a," and "A a" should all receive yes responses.

Hunt et al. (1975) designed their experiment according to the following logic: A person's being highly verbal ought to imply "an ability to interpret arbitrary stimuli" and, in particular, an ability to translate "from an arbitrary visual code to its name" (p. 200). Thus they expected the highly verbal students to be especially adept in the name match condition, relative to the students of less verbal ability.

Indeed, as Figure 15-2 indicates, this is what they found. Both groups were approximately equally fast in the physical match condition (the highly verbal group was in fact a little faster here, too); the highly verbal group's superiority really became evident only when the task became a little more complex. The authors explained that high verbal ability stems at least in part from an ability to make a conversion rapidly between a physical stimulus and a conceptual meaning—in this case, recognition of the particular letters.

**FIGURE 15-2** ■ *Mean reaction time (RT) for high- and low-verbal participants in a perceptual matching task.*

**SOURCE:** Adapted from Hunt et al. (1975).



Psychologists and educators debate fiercely the issue of whether intelligence is one thing or several. A controversial popular book, *The Bell Curve* (Herrnstein & Murray, 1994), stirred a simmering pot of contention when it appeared, making (among others) the following strong assertions:

> Here are six conclusions regarding tests of cognitive ability, drawn from the classical tradition, that are by now beyond significant technical dispute:
>
> 1. There is such a thing as a general factor of cognitive ability on which human beings differ.
> 2. All standardized tests of academic aptitude or achievement measure this general factor to some degree, but IQ tests expressly designed for that purpose measure it most accurately.

3. IQ scores match, to a first degree, whatever it is that people mean when they use the word *intelligent* or *smart* in ordinary language.
4. IQ scores are stable, although not perfectly so, over much of a person's life.
5. Properly administered IQ tests are not demonstrably biased against social, economic, ethnic, or racial groups.
6. Cognitive ability is substantially heritable, apparently no less than 40 percent and no more than 80 percent. (Herrnstein & Murray, 1994, pp. 22–23)

A large part of the reaction to this work stemmed from what critics took to be the authors' refusal to present other points of view in a balanced or responsible way (Gould, 1995; Kamin, 1995). Many critics in particular decried the idea that there is one basic cognitive ability, called intelligence, that is accurately measured by IQ (intelligence quotient) tests. Many others complained about the assumption that intelligence (whatever it is) is fixed and heritable.

One theorist, Howard Gardner (1983, 1993, 1999), had previously offered a theory directly contradicting the claims of Herrnstein and Murray. Gardner (1993) offered what he called a "pluralistic" theory of mind. He began by questioning what "an intelligence" is and offered this definition: "the ability to solve problems, or to fashion products, that are valued in one or more cultural or community settings" (p. 7). On the basis of a review of clinical data with brain-damaged individuals, studies of prodigies and gifted individuals, and experts in various domains from various cultures, Gardner (1983) proposed the existence of (at least) seven distinct, independent "human intellectual competences, abbreviated hereafter as 'human intelligences'" (p. 8). These intelligences, with two others added in Gardner's 1999 work, are listed in Table 15-1.

Gardner (1983, 1993, 1999) argued that our Western culture places certain kinds of intelligence, specifically linguistic and logical-mathematical, on a pedestal. At the same time our culture gives short shrift to the other intelligences, especially bodily-kinesthetic and interpersonal. We regard skilled athletes or politicians as people with talents, but not as people who have a different sort of intelligence, like famous scientists or great poets. We make a distinction between talents and intelligence, Gardner believes, only so that we can hold onto the concept that there is only one mental ability. Gardner calls for a broader view of people's mental and cognitive abilities. He argues for a different kind of schooling that, instead of focusing only on linguistics and logic, also trains students as carefully in music, self-awareness, group processes, dance, and the performing arts.

Gardner's theory has captured the attention and enthusiasm of many psychologists and educators, some of whom are trying to implement the previously described **multiple intelligences (MI) theory** in their classes (see Gardner, 1993 and 1999, for some descriptions). There exist proposals for multiple creativities as well as intelligences, and educators have adopted these ideas enthusiastically

**Table 15-1 Multiple Intelligences**

| | |
|---|---|
| *Linguistic intelligence* | The capacity to use language to communicate and to accomplish other goals; sensitivity to subtleties in both written and spoken language; the ability to learn foreign languages. |
| *Logical-mathematical intelligence* | The ability to solve problems, design and conduct experiments, draw inferences; the capacity to analyze situations. |
| *Musical intelligence* | The ability to analyze and respond to musical patterns; to compose or perform music. |
| *Bodily-kinesthetic intelligence* | The ability to use one's body to perform artistically or athletically; to create physical products; to use either the whole body or parts of the body skillfully. |
| *Spatial intelligence* | The ability to navigate skillfully through both wide and confined spaces; to visualize spatial scenes; to create products with spatial properties. |
| *Interpersonal intelligence* | The capacity to understand other people's emotions, motivations, intentions, and desires; the ability to work effectively with others. |
| *Intrapersonal intelligence* | The ability to understand one's own emotions, motivations, intentions, and desires, and to use the information for self-regulation. |
| *Naturalist intelligence* | The ability to recognize flora and fauna of one's environment; to skillfully classify organisms with respect to species and to chart the relationships among different species. |
| *Existential intelligence* | The capacity to see one's place in the cosmos, especially in light of such issues as the nature of the human condition, the significance of life, the meaning of death, the ultimate fate of the world, both physical and psychological. (*Note:* Gardner is still evaluating whether this capacity fully merits the label "intelligence.") |

**Note:** The first seven items were presented in Gardner (1983); the last two come from Gardner (1999).

**Source:** Adapted from Gardner (1999).

(Han & Marvin, 2002). However, Gardner's theory awaits the development of assessment tools for each intelligence.

Researchers and educators who hold to the concept of IQ as measuring the one true mental ability called intelligence have sophisticated tests that generally predict school performance adequately. Those interested in the idea of multiple intelligences have a great deal of work ahead of them to define the parameters of all the intelligences, to create valid measures of each, and to describe the interrelationships among different kinds of intelligences.

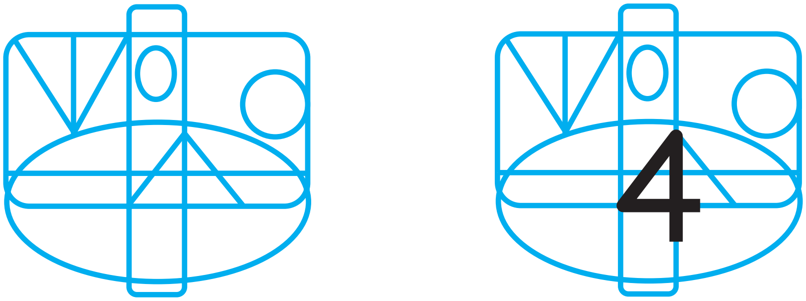
## Cognitive Styles

Gardner's theory of multiple intelligences points to the idea that people differ in their cognitive equipment. This idea comports well with another long-standing idea: that people differ not only in their abilities, capacities, and the efficiency with which they use each, but also in terms of their **cognitive style,** their habitual and preferred means of approaching cognitive tasks (Globerson & Zelnicker, 1989; Tyler, 1974). The term *cognitive style* is meant to imply certain personality and motivational factors that influence the way in which a person approaches a cognitive task (Kogan, 1983).

One example of a type of cognitive style is **field dependence/field independence (FD/FI),** a term coined by psychologists who studied perceptual processing (Witkin, Dyk, Faterson, Goodenough, & Karp, 1962; Witkin & Goodenough, 1981). The term refers to several phenomena, one of which is that some people find it much easier than other people to identify parts of a figure as separate from a whole. An example of a task of field independence is shown in Figure 15-3. Field-dependent individuals would have a more difficult time finding the embedded picture in the larger picture (they are less able perceptually to divorce the embedded picture from its context), whereas field-independent people would find this task relatively easy.

Witkin and his associates see this style of cognition as related to issues broader than perception of figures. According to the theory, this cognitive style refers to "the degree to which the person relies primarily on internal [field-independent, FI] or external [field-dependent, FD] referents in processing information from the self and the surrounding field" (Kogan, 1983, p. 663). Later conceptualizations broadened the definition of the style still more, associating

**FIGURE 15-3** ■ *Example of an FD/FI test item.*



Item: Find the "4" in the figure above.

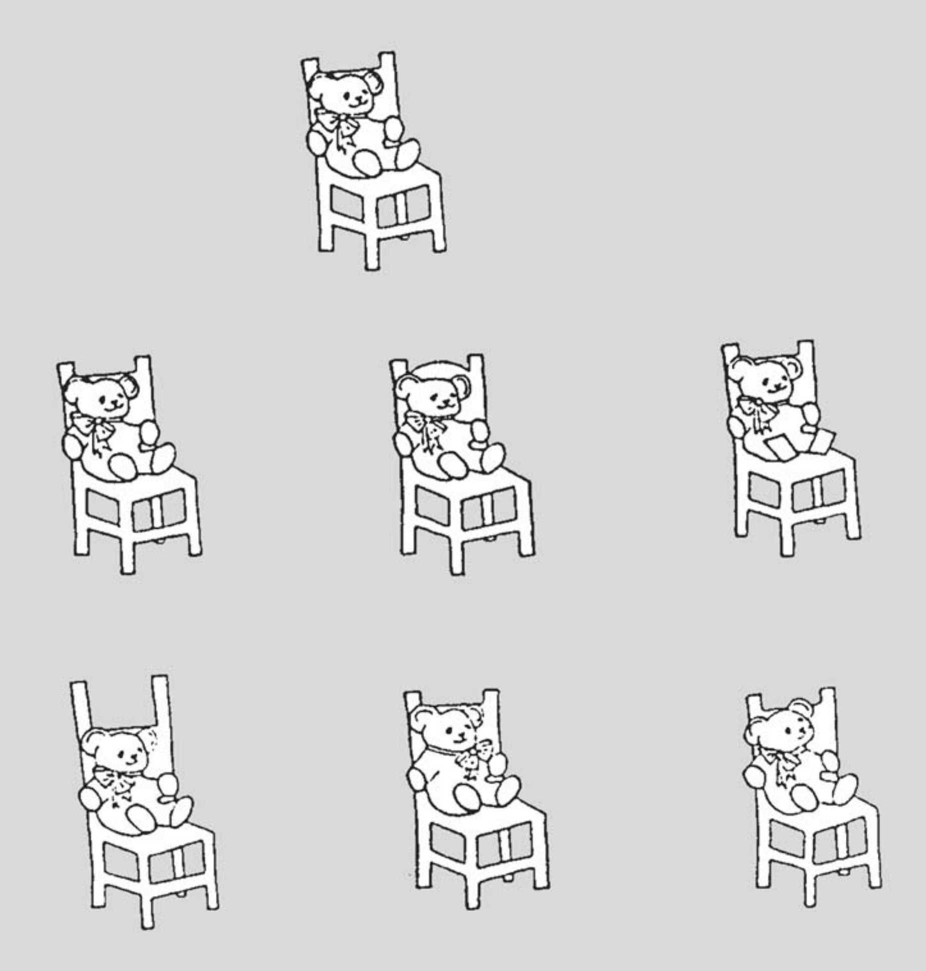
Correct response

the FI style with a generally autonomous manner in interpersonal relationships (a person who might be likely to form her own opinions, regardless of what her friends thought), whereas FD individuals are seen as more likely to rely on others, especially in ambiguous situations.

A second example of different types of cognitive styles has been called **cognitive tempo,** or style of **reflectivity/impulsivity.** Kogan (1983) defined this style as "the extent to which a child delays response in the course of searching for the correct alternative in a context of response uncertainty" (p. 672). This can be illustrated with reference to Figure 15-4, depicting an item from the

**FIGURE 15-4** ■ *Example of an MFFT item.*

**SOURCE:** Kagan et al. (1964, p. 22).



Matching Familiar Figures Test (MFFT), developed by Kagan and his associates to assess cognitive tempo (Kagan, Rosman, Day, Albert, & Phillips, 1964).

The task posed to respondents is to find the item that exactly matches the item shown at the top. As you look at the other six pictures, notice that each is very similar to the top item and that to find the one that exactly matches requires your careful attention. Children vary in how they respond to MFFT items. Some respond very quickly; others, more slowly. Some make very few errors, even on difficult items; others make a number of errors, even on easy items. Many children fall into two categories: those who respond rapidly and make many errors (demonstrating an impulsive style) and those who respond slowly, with relatively few errors (demonstrating a reflective style) (Tyler, 1974).

Originally, cognitive styles were thought of as optional, modifiable manners or problem-solving approaches that were independent of both intelligence and age. More recent research has challenged these assumptions. Cognitive styles do not appear easily modified through training. Moreover, cognitive styles show developmental differences; younger children are more likely to display impulsive and field-dependent styles, and older children, more reflective and field-independent styles (Zelnicker, 1989).

Zelnicker (1989) also argued that reflectivity/impulsivity and FD/FI are not completely independent dimensions and that each relates to three underlying dimensions: selective attention, in particular the tendency to respond to whole stimuli or to their parts; attentional control, the focusing and shifting of attention; and stimulus organization, the mental transformation of stimulus input (for example, in mental rotation tasks as described in Chapter 9). Zelnicker asserted that an individual's cognitive style "determine[s] the quality of stimulus information accessible for further processing in solving . . . problems" (p. 187).

Some psychologists are now turning their attention to whether people with different cognitive styles approach learning tasks differently. One example comes from the work of Rollock (1992), who gave 35 field-independent and 42 field-dependent undergraduates a task in which they listened to an audiotaped lecture followed by a quiz and then participated in an interactive demonstration followed by another quiz. They thought that the first learning condition would favor field-independent learners and that the second would favor field-dependent students. Although the first prediction was not supported, the second one received marginally significant support. Other researchers have looked at people with so-called visual versus verbal learning styles (Green & Schroeder, 1990), although again with mixed results in supporting the idea of distinct styles. The general idea here is that learners learn best when the mode of information presentation best suits their own individual learning style. Much work remains to be done to test this premise empirically.

Another recent area of attention among cognitive style researchers concerns a concept called **need for cognition,** which roughly means a person's motivation to take on intellectual tasks and challenges (Cacioppo & Petty, 1982). Individuals with high need for cognition (NFC) seem to enjoy more those kinds of endeavors that involve thinking, problem solving, and reasoning, and to derive more satisfaction from accomplishing an intellectual challenge than do individuals with a lower NFC. For example, high-NFC individuals might enjoy doing crossword or Sudoko puzzles as a form of recreation, whereas low-NFC individuals might enjoy recreation that involves less intellectual engagement, such as watching TV game shows. Klaczynski and Fauth (1996) demonstrated no significant relationship between NFC and cognitive ability, suggesting that NFC really is a stylistic dimension, not derived from intellectual power such as IQ. At the same time, the authors showed that low-NFC individuals were more likely to drop out of college, suggesting that styles do affect important life outcomes. Stanovich and West (1997, 1998, 2000) have gone on to show that cognitive style measures such as NFC do correlate with performance on a variety of specific reasoning and decision-making tasks.

## Expert/Novice Differences

Throughout earlier chapters, we have seen that people with expertise in a certain realm often approach a cognitive task differently from novices. We first encountered this topic in Chapter 3 when we discussed perceptual learning. If you recall, the point was made there that experts and novices, given equal exposure to information, acquire or "pick up on" different amounts of it. In general, experts will perceive more distinctions, especially subtle ones, than novices do. This point is illustrated in an example of an art historian and a layperson unfamiliar with art standing before a Picasso painting. The layperson (novice) "sees" less information than the art historian (expert), who may be rather effortlessly picking up information about brushstrokes or composition that the novice simply cannot perceive.

We saw next in Chapter 8 that experts and novices differ in their conceptual representations of information. Novices in a given domain, for example, tend to classify objects or instances together on the basis of superficial or perceptual similarities; experts often use their knowledge to form deeper principles with which to classify. For example, if given a number of paintings, a novice might categorize on the basis of the subject of the picture (landscapes, still lifes, portraits). An art expert would be far more likely to categorize on the basis of artist, historical period, composition, and other aspects of a painting that require a certain degree of knowledge.

Work by de Groot (1965) and Chase and Simon (1973) on chess experts and chess novices has suggested other relevant cognitive-processing differences between the two groups. For example, when shown a chessboard arranged in a midgame configuration (that is, the pieces arranged in such a way as to represent a game in process), an expert chess player could reconstruct the positions of approximately 16 (out of 25) pieces after only a 5-second glance. A chess beginner, given the same board and the same exposure, could reconstruct the positions of only about 5 pieces.

Interestingly, the authors showed it was not simply that the experts had better memories. Indeed, when shown chessboards with 25 chess pieces randomly arranged on them, the expert and the beginner showed equivalent performance, being able to reconstruct the positions of only 2 or 3 pieces. Instead, Chase and Simon (1973) argued that the chess expert used chess knowledge to group or "chunk" chess pieces into meaningful configurations. As Chapter 5 suggests, the chunking process can increase the amount of information held in working memory.

The findings on **expert/novice differences** just described sound a common theme: Your level of knowledge in a domain affects your cognition within that domain. Many cognitive processes, including perception and recognition, encoding, classification and categorization, and problem solving, reasoning, and decision making about information within the domain of expertise, appear affected.

## ■ THE EFFECTS OF AGING ON COGNITION

We saw in the previous chapter that cognitive skills and abilities develop, which means that children of different ages and levels of development may approach the same cognitive task in different ways. Age-related changes in cognitive processing do not cease in adolescence. In fact, researchers looking at adult development and aging have found a number of differences in cognitive processing between younger and older adults. Once again, this topic is a broad one, and we have space to mention only a few examples.

Relative to younger adults (those in their 20s and 30s), older adults (those in their 60s and older) show several differences in cognitive abilities and skills. For example, older adults perform less well on tasks of divided attention (such as those discussed in Chapter 4; McDowd & Craik, 1988); show age-related decrements in speech recognition and speech discrimination (Corso, 1981); and show declines in memory performance on a variety of memory tasks (Cavanaugh, 1993), as well as on a Tower of Hanoi problem-solving task (Davis & Klebe, 2001).

One example of these findings has to do with performance on working-memory tasks. Salthouse and Babcock (1991) studied the performance of adults aged 18 to 87 on various working-memory tasks, such as digit span, sentence comprehension, and mental arithmetic. The authors found, first, that older participants had shorter spans than younger participants. They hypothesized, after extensive statistical analyses of their data, that the major factor accounting for this decline in span length was a decline in processing efficiency, or the speed with which various elementary cognitive operations (such as performing simple addition or comprehending a simple sentence) could be carried out.

Campbell and Charness (1990) found similar age-related declines in working memory. They gave three groups of adults (20-, 40-, and 60-year-olds) a task in which they learned an algorithm for squaring two-digit numbers. Participants worked for six sessions lasting an hour or two each. The authors report two significant findings. First, practice with the algorithm improved performance, in that errors declined over sessions. However, adults in the oldest group made more errors than the "middle-aged" adults, who in turn made more errors than the youngest adults. Even with practice, these age differences remained.

Hulton-Deutsch Collection/CORBIS

*Famed pianist Arthur Rubinstein maintained his expert level of performance by adopting specific strategies as he got older.*

Baltes, Staudinger, and Lindenberger (1999), in a review of the literature, concluded that a general decline in the speed of processing of elementary cognitive operations occurs with age, perhaps accounting for the pattern of findings just reviewed. Paul Baltes and Margaret Baltes, well-known researchers on aging, have argued, however, that older adults often can strategically compensate for such declines by using selective optimization with compensation:

> When the concert pianist Arthur Rubinstein, as an 80-year-old, was asked in a television interview how he managed to maintain such a high level of expert piano playing, he hinted at the coordination of three strategies. First, he played fewer pieces (selection); he practiced these pieces more often (optimization); and to counteract his loss in mechanical speed he now used a kind of

> impression management, such as playing more slowly before fast segments to make the latter appear faster (compensation). (Baltes et al., 1999, pp. 483–484)

It is important to keep in mind, however, that differences in cognitive processing as a function of aging are still subject to individual differences from other sources. Such factors as intelligence, health, years of formal education, expertise, and cognitive style all continue to play important roles. The topic of the effects of aging on cognition, still in its relative scholarly infancy, will no doubt continue to support the idea that any individual's level of cognitive functioning depends on many factors, including factors specific to the individual, such as those just described, as well as those of the task and the overall context (Lerner, 1990).

This brief look at individual differences in cognitive abilities was intended to stress an important point: Not all people approach cognitive tasks in exactly the same way. Age, ability, expertise, and stylistic differences among people can affect their efficiency in acquiring or processing information, leading to differences in how much information is picked up or how thoroughly it is processed. These differences, in turn, could have great effects on how well a complicated cognitive task is performed.

In the last four decades, some psychologists have also wondered about the existence of gender as a source of individual differences in cognition. In the next section, we will examine whether men and women adopt different cognitive styles or strategies in their approaches to cognitive tasks.

## GENDER DIFFERENCES IN COGNITION

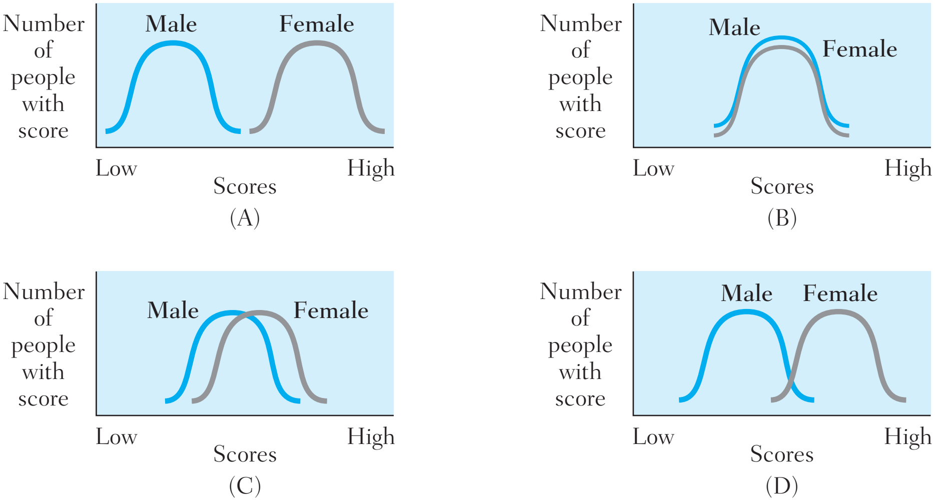
The possible existence of gender differences can be fascinating. This fascination is especially pronounced in our culture, as psychologist Carol Nagy Jacklin (1989) noted:

> Speculation about differences between females and males is a national preoccupation. In our culture, people care whether there are fundamental differences between girls and boys, and we place more emphasis on the possibility of such differences than on other kinds of distinctions that could be made. For example, we rarely wonder whether blue-eyed and brown-eyed or short and tall children differ from one another in intellectual abilities or personality. (p. 127)

Some cautions are in order before we examine the evidence regarding gender differences in cognition, especially because of the sensitive nature of the topic. One of the most important cautions regards the term *gender difference*.

To say there is a gender difference in performance on Task X can mean a number of very different things, as illustrated in Figure 15-5. One possible meaning is that the scores from members of one sex are higher than the scores from members of another sex, a possibility illustrated in Figure 15-5(A). Notice that the lowest-scoring member of one sex (the distribution to the right) still outperforms the very best member of the lower-scoring sex. Although many people interpret statements about gender (or other group) differences in these terms, reality is almost never this simple.

**FIGURE 15-5** ■ *Examples of hypothetical gender distributions. Each curve depicts a hypothetical distribution of scores on some test for persons of one gender.*



More realistic depictions of gender differences in performance are given in Figures 15-5(B), 15-5(C), and 15-5(D). The first illustrates no gender difference. The last two illustrate real gender differences in the mean level of performance, with different degrees of overlap in scores between people of different genders. In each case, although females on average score higher than males, some males score higher than some females. In both cases, then, it is impossible to predict how any individual (Sally Smith or Jack Jones) would score. All we can say is that given large numbers of men and women, the average score for women will be higher than the average score for men.

A second caution concerns built-in biases in the research literature. Scientific journals are simply much more likely to publish research that reports significant differences between or among groups of people than to include research that does not find differences. (This is known as the "file drawer problem," because most studies that do not obtain statistically significant results often languish in a researcher's file drawer.) In part, this is because journal space is limited, and studies that find differences tend to be more interesting than those that don't (Tavris & Wade, 1984). In part, this is also because of difficulties in interpretation: Researchers who find no group differences cannot conclude there are no differences. Halpern (1992) explains why:

> Suppose you formulate the null hypothesis that no one has more than or less than one head. You could collect a large sample of people, count the number of heads per person, and presumably find that each has only one. However, you have not proved the null hypothesis, because only one exception, that is only one person with more or less than one head, can disprove it, and it is possible that you failed to include this person in your sample. Similarly, even large amounts of negative evidence cannot be used to prove that sex differences do not exist. (p. 33)

Another set of problems in interpreting research on gender differences concerns **experimenter expectancy effects,** the tendency for researchers unintentionally to influence the responses or behavior of research participants in the direction of the experimenter's hypothesis (Rosenthal & Rosnow, 1984). To remind you, we first discussed the influence of such effects in Chapter 9, when we reviewed imagery studies.

In many psychological studies, experimenters can avoid or minimize these effects by remaining "blind" to which condition a participant is in. For example, in a memory study, one experimenter could randomly assign participants to the experimental and control groups, and a second experimenter, who did not know which of them came from which groups, could administer the tests.

With gender differences research, however, it is a different story. Whenever participants are observed or interviewed, it is almost impossible for the observer or interviewer to remain blind to the participant's gender. Thus the observer or interviewer runs a risk of unintentionally and subtly "leading" the participant to behave in ways consistent with the study's hypotheses, cultural stereotypes, or both. For example, an interviewer who expects women to be more "verbal" or more "emotionally expressive" may unconsciously reinforce this behavior in women, perhaps by smiling more, thereby allowing or encouraging more responses in the predicted direction. Some studies can avoid these problems by having participants respond in writing (and then having their responses typed and scored by raters who do not know the gender of the writer), but this limits

Chabruken/Getty Images

*In a face-to-face interview, it is impossible to keep the respondent's gender hidden from the experimenter. This can lead the interviewer to guide the discussion, or subtly reinforce certain responses, as a function of her gender-based expectations of the respondent.*

the kinds of observations and data that can be collected. For these reasons, it is important to keep in mind throughout our discussion that there can be significant problems of bias, particularly in studies of gender differences.

## Gender Differences in Skills and Abilities

Is there an overall difference in cognitive ability between women and men? Many people in our culture have different and strongly held opinions on this question (for example, "Everyone knows men are smarter" or "Women are smart enough to let men think that they [the men] are more talented"). But a cognitive psychologist needs more than opinion, however loudly voiced. Asked this question, she must first begin by defining what it means to have greater overall cognitive ability and must then translate this definition into specific behaviors or patterns of responses on specific tasks (this is called *operationalizing* the question—making it operational). Finally, she must recruit appropriate samples of men and women and administer the chosen tasks.

One kind of task the psychologist might choose is an intelligence test. However, a problem with this approach stems from the way intelligence tests are constructed. As Halpern (1992) pointed out, constructors of intelligence tests work hard to ensure that no overall differences exist between the scores of men and women. That is, many test constructors exclude from intelligence tests any items that show a reliable gender difference in responses.

However, this does not mean that men and women never show any differences in cognitive performance. In an early classic—but later heavily criticized—review of the sex differences literature, Maccoby and Jacklin (1974) identified three kinds of cognitive abilities that appeared to show reliable gender differences: verbal abilities, visuospatial abilities, and quantitative abilities. In this section, we will look at each of these in turn.

To do so, we will need first to consider methodological techniques used by psychologists when reviewing existing literature. Three major kinds of techniques have been used. The first, *narrative review,* involves locating and reading as many sources as one can and then writing up one's conclusions. Although such summaries can be useful, Hyde and Linn (1988) pointed out that the narrative review has several shortcomings: "It is nonquantitative, unsystematic, and subjective, and the task of reviewing 100 or more studies simply exceeds the information-processing capacities of the human mind" (p. 54).

A second technique, used by Maccoby and Jacklin (1974), is called *vote counting*. As the name implies, it involves listing each study and counting the number of studies in the total that demonstrate a particular effect. In essence, each study then receives one "vote" in the final tally. Studies that do demonstrate a gender difference "vote" for the idea that gender differences really exist; studies that do not find a gender difference "vote" for the opposite proposition. Although an advance over the narrative review, vote counting still suffers from a number of problems. The most important is that each study is given equal weight, although many studies differ in overall quality, sample sizes, precision of the instruments used, and statistical power (Block, 1976; Hedges & Olkin, 1985; Hyde & Linn, 1988).

A more powerful technique for combining results from different studies is called **meta-analysis.** It involves the use of statistical methods in integrating the findings from different studies (Hedges & Olkin, 1985). This approach is gaining widespread popularity among psychologists. It allows the investigator to compare different studies quantitatively. A measure commonly used in meta-analysis is ***d,*** defined as the difference in mean scores between two groups, divided by the average standard deviation for the two groups. This measure is known as the **effect size.**

To take a concrete example of effect size, consider the following example: Suppose women outperform men on a specific verbal task. If the mean score for women is 100 and the mean score for men is 50 but if, on average, the standard deviation for the two groups is 75, the effect size of the study would be [100 – 50]/75, or .67. Essentially, an effect size tells us how much standardized difference lies between two (or more) means. Cohen (1969) provided rules of thumb for interpreting this value: Effect sizes of .20 are considered small; of .50, medium; and of .80, large. So our hypothesized value of .67 would count as a medium-to-large effect.

### Verbal Abilities

What kinds of abilities count as "verbal abilities"? Different authors provide different definitions, of course, but a typical description includes breadth of vocabulary, speech fluency, grammar, spelling, reading comprehension, oral comprehension, and the ability to solve language puzzles such as verbal analogies or anagrams (Halpern, 1992; Williams, 1983). Maccoby and Jacklin (1974) concluded that the bulk of studies conducted up until 1974 suggested that although girls and boys showed approximately the same pattern of verbal abilities, after about age 11 and continuing through high school and beyond females outperformed males on a variety of verbal tasks, including language comprehension and production, creative writing, verbal analogies, and verbal fluency.

A review (Hyde & Linn, 1988) challenged Maccoby and Jacklin's conclusion. Using meta-analysis, the authors surveyed 165 studies (both published and unpublished) that met the following criteria: Participants were from the United States and Canada, were over 3 years old, and lacked language deficits (such as dyslexia); the studies reported original data; and the authors provided enough information for the calculation of effect sizes. The types of verbal abilities examined included vocabulary, analogies, reading comprehension, oral communication, essay writing, general ability (a mixture of other measures), SAT verbal scores, and anagrams.

Of the studies surveyed, roughly a quarter showed superior male performance; three quarters showed superior female performance. However, when data were assessed in terms of statistical significance, only 27% of the studies found statistically significant higher female performance, 66% found no statistically significant gender differences, and 7% found statistically significant higher male performance. When the types of verbal tasks were taken into account, the only tasks to show reliable female superiority were those for anagrams, speech production, and general ability. The average *d* measures for these tasks were .22, .20, and .33, respectively, suggesting that even the significant gender differences were rather small. Analyzing gender differences as a function of age, the authors also found little variation in *d* measures according to whether the participants were preschoolers, children of elementary school age, adolescents, or adults.

Nancy J. Ashmore

*Early work suggested that females had greater verbal abilities than males. More recent analyses, however, have disputed this claim. The gender differences, if they exist, are small at best.*

Interestingly, studies published before 1973 showed a significantly larger gender difference (mean *d* = .23) than did more recent studies (those published after 1973; mean *d* = .10). Early work suggested that females had greater verbal abilities than males; more recent analyses, however, disputed this claim. Hyde and Linn (1988) concluded:

> We are prepared to assert that there are no gender differences in verbal ability, at least at this time, in American culture, in the standard ways that verbal ability has been measured. We feel that we can reach this conclusion with some confidence, having surveyed 165 studies that represent the testing of 1,418,899 subjects . . . and averaged 119 values of *d* to obtain a mean value of 10.11. A gender difference of one tenth of a standard deviation is scarcely one that deserves continued attention in theory, research, or textbooks. Surely we have larger effects to pursue. (p. 62)

## Visuospatial Abilities

The term *visuospatial abilities* is awkward and hard to define, as previous authors have noted (Halpern, 1992; McGee, 1979; Williams, 1983). Typically, it refers to performance on tasks such as the mental rotation or mental transformation of different objects, shapes, or drawings, similar to those described in Chapter 9. Maccoby and Jacklin (1974) reported gender differences in visuospatial abilities as extremely reliable, asserting that boys "excel" in them once childhood is over. They reported a *d* measure of up to .40.

One task that appears to show reliable gender differences is mental rotation. On average, males perform better than females, although many individual females can outperform many individual males, even on this task. Over the past 25 years, researchers have reported consistently large (*d* = .90) gender effects on mental rotation tasks (Loring-Meier & Halpern, 1999).

Loring-Meier and Halpern (1999) performed a study to investigate which components of a mental rotation task showed gender differences. Was it the initial generation of an image? The maintenance of an image in working memory? The ability to scan a mental image? The ability to transform a mental image? The researchers had 24 males and 24 females complete four tasks originally designed by Dror and Kosslyn (1994). Two of the four tasks are described here.

Nancy J. Ashmore

*One task that appears to show reliable gender differences is that of mental rotation. On average, males perform better than females. However, many individual females can outperform many individual males, even on this task.*

The first, an image generation task, asked participants to image a particular block letter, say L, by cueing it with a script lowercase version of the letter, say ℓ. Following this, a set of four brackets would appear, with an X mark appearing somewhere within it. The participant had to decide whether the X appeared within the space where the uppercase block letter would be if it had been drawn inside the four brackets. Figure 15-6 provides an example.

The image maintenance task presented participants with a pattern such as the one shown in Figure 15-7. Participants were asked to memorize the pattern and press a key, causing the pattern to disappear. After an interval of 2500 milliseconds, the screen presented an X and the participant had to decide if the pattern would have covered the X.

Results showed that, for all four tasks, there was no difference in accuracy between males and females. However, on all four tasks males were reliably

**FIGURE 15-6** ■ *Examples of a stimulus presented during the learning stage (A) and a trial sequence in the image generation task (B).*

**SOURCE:** Loring-Meier and Halpern (1999, p. 466).

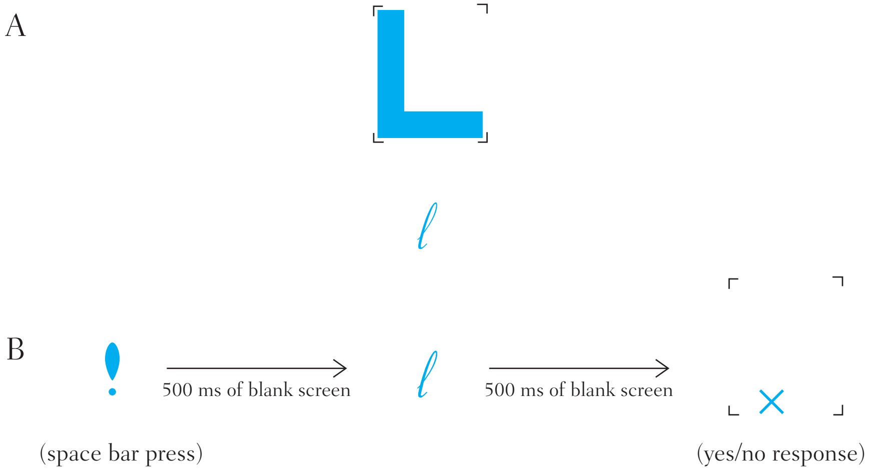
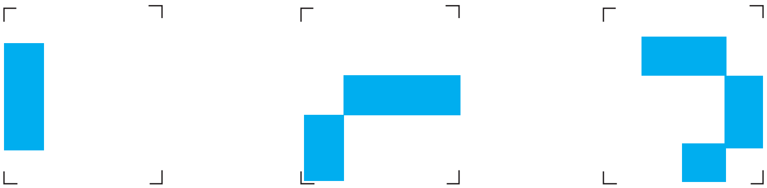


**FIGURE 15-7** ■ *Examples of stimuli used for the image maintenance task.*

**SOURCE:** Loring-Meier and Halpern (1999, p. 468).



faster than females, leading the authors to conclude that "males, in general, are more proficient in their use of visuo-spatial imagery" (Loring-Meier & Halpern, 1999, p. 470).

Linn and Petersen (1985), who conducted a meta-analysis of gender differences in spatial ability, concluded that the size of the gender difference in mental rotation differs as a function of the specific task. Generally speaking, the more rapid processing of symbolic information required, the larger the gender difference. Mental rotation tasks that involved complex three-dimensional items generally showed larger gender differences than did mental rotation tasks with simpler, two-dimensional items. Linn and Petersen (1985) offered a number of possible reasons for the gender difference; for example, females may rotate items more slowly or may use different strategies in approaching the task.

Another reason may have to do with neurological findings on male and female brains. In a review, Levy and Heller (1992) noted that, in general, females tend to have cerebral hemispheres that are less lateralized, or specialized in function, than are the cerebral hemispheres of males. It has long been known in psychology, as we discussed in Chapter 2, that the cerebral hemispheres have slightly different roles to play in our cognitive lives. For most of us (especially right-handed people), verbal fluency, verbal reasoning, and other types of analytical reasoning seem to be governed by left-hemisphere functioning. The right hemisphere, in contrast, seems specialized for understanding spatial relations as well as for interpreting emotional information.

To say that males are more lateralized than females is to say that males show greater asymmetries in the functioning of their two cerebral hemispheres. Females, for example, appear to have language functions represented in both hemispheres, at least to some degree. Related to this, women who suffer left-hemisphere damage often show better recovery of language functioning than do men with the same type of damage (Levy & Heller, 1992).

What might it mean to have greater asymmetries in functioning? It probably implies greater specialization in functioning; the more specialization, the more resources one has to perform a task. Overall, males' greater lateralization may equip them with more resources to devote to specific spatial tasks, such as mental rotation. Of course, this conclusion must be interpreted carefully. Although a gender difference in lateralization is well documented, this does not imply that every male shows greater lateralization than every female. Moreover, the tasks on which gender differences in spatial ability have been found are restricted to a narrow set.

A very recent study (Levine, Vasilyeva, Lourenco, Newcombe, & Huttenlocher, 2005) adds a new wrinkle to the idea of gender differences in spatial abilities. These authors gave two spatial and one nonspatial task to boys and girls over a one-year period, beginning in the participants' second-grade year. They found no gender differences in the nonspatial (syntax comprehension) task, as expected. Also as expected, there was an overall gender difference in performance on the two spatial tasks (mental rotation and making correspondences between photographs and maps). Surprisingly, however, this overall difference showed variation as a function of the children's socioeconomic status (SES), as shown in Figure 15-8. Specifically, lower-SES students did not show any gender difference on the tasks; only middle- and high-SES students exhibited the traditional

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male advantage on the spatial tasks. One possible explanation for the SES-related differences is as follows:

> An alternative explanation for the SES-related difference is that a differentially high level of engagement in the kinds of activities that promote the development of spatial skill is essential to the male spatial advantage. In lower-SES groups, these kinds of activities may be relatively unavailable to both boys and girls. Although little is known about what types of input can promote spatial skills, prior studies indicate that activities such as playing with Legos, putting puzzles together, and playing video games are correlated with spatial skill; further, boys spend more time on these acitivies than girls. . . . Although low-SES children certainly engage in sex-typed play, they may have less access than other children to toys and games that promote spatial skill, as some of these toys and games are relatively expensive. (Levine et al., 2005, p. 844)

Ultimately, the reasons for a gender difference in spatial ability may be found in biological factors, such as lateralization; socialization factors, such as access to puzzles and video games; or some combination. In any event, however, the differences have implications—for example, for the developers of important standardized tests such as the GRE and SAT:

> Many questions on these tests require the generation, maintenance, and transformation of visuospatial configurations. . . . On average, males score higher than females on these high-stakes tests. . . . These are speeded tests, which means that test takers who answer questions quickly are at an advantage compared with those who respond more slowly. (Loring-Meier & Halpern, 1999, p. 470)

## Quantitative and Reasoning Abilities

The term *quantitative abilities* covers a variety of skills, including arithmetic knowledge and skill as well as understanding of quantitative concepts (such as fractions, proportions, inverses). As with the terms *verbal abilities* and *visuospatial abilities,* the term *quantitative abilities* has meant slightly different things to different investigators.

Maccoby and Jacklin (1974) believed that boys and girls showed similar levels and patterns of mathematical ability through elementary school. Beginning at age 12 or 13, however, boys' achievement and skill began to increase faster than girls'. Hyde (1981), conducting a meta-analysis of the studies originally cited by Maccoby and Jacklin, concluded that the median *d* score for all the studies was .43, showing that, on average, boys tend to outperform girls by about a half a standard deviation.

Studies by Benbow and Stanley (1980, 1983) provided more evidence in support of gender differences in mathematical ability. The investigators used data collected by the Study of Mathematically Precocious Youth (SMPY), a talent search used to identify extremely able junior high school students. The logic here is that until junior high, male and female students are exposed to the same math classes in school. Thus using junior high school students reduced the role of differential exposure to mathematics that might occur in high school, when males often enroll in more math classes than females.

In the SMPY studies, seventh- and eighth-graders took the College Board's SAT, a familiar test for high school juniors and seniors. Table 15-2 presents some of the results. Benbow and Stanley (1980) found that males' score on the mathematical section of the SAT were approximately 30 points higher than females', although both groups performed equally well on the verbal section. Moreover, the higher the score, the higher the ratio of men to women who have that score. For example, considering SAT scores of 700 and above (only 1 in 10,000 students scores this high), the ratio of men to women is 13 to 1 (Benbow & Stanley, 1983). There is some evidence, however, that gender differences occurred only on specific items, usually having to do with algebra rather than with geometry or arithmetic (Deaux, 1985).

Follow-up investigations of the SMPY students, conducted 20 years after they were first studied, revealed that gender differences did predict different outcomes in educational pursuit of degrees either in or related to mathematics (for example, engineering, computer science, physical sciences). Males were five to seven times more likely than females, for example, to obtain a doctorate in one of these areas. In the surveys, males endorsed more highly than females the desire for achievement in their careers, whereas women endorsed more highly than men the desire for a balanced life (Benbow, Lubinski, Shea, & Eftekhai-Sanjani, 2000; Lubinski, Webb, Morelock, & Benbow, 2001).

Anita Meehan (1984) examined gender differences in other, related tasks, specifically Piagetian tasks of formal operations. Recall from Chapter 14 that formal-operational tasks include such things as logical reasoning, the ability to think systematically, and the ability to consider all possibilities. Meehan examined three kinds of formal-operational tasks: propositional logic tasks, combinatorial reasoning tasks, and proportional reasoning tasks. Performing meta-analyses on a total of 53 studies, Meehan discovered small and statistically nonsignificant values of $d$ for the first two tasks, .22 and .10, respectively. The third task, a more explicitly quantitative task (having to do with ratios), showed an average $d$ of .48.

We have seen so far that gender differences on some cognitive tasks—namely, some visuospatial and some quantitative tasks—seem established. However, Hyde (1981) made an important point: A statistically reliable effect need not necessarily be a large effect. One way to measure the magnitude of an effect is to compute a quantity known to psychologists as the "percentage of variance accounted for." In lay terms, this measure reflects how much of the

**Table 15-2** Mean SAT Scores of Mathematically Precocious Youths

| | | Number | | SAT-V Score[*] ($\bar{x}$ ± S.D.) | | SAT-M Scores[†] | | | | Percentage Scoring Above 600 on SAT-M | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $\bar{x}$ ± S.D. | | Highest Score | | | |
| Test Date | Grade | Boys | Girls | Boys | Girls | Boys | Girls | Boys | Girls | Boys | Girls |
| March 1972 | 7 | 90 | 77 | | | 460 ± 104 | 423 ± 75 | 740 | 590 | 7.8 | 0 |
| | 8+ | 133 | 96 | | | 528 ± 105 | 458 ± 88 | 790 | 600 | 27.1 | 0 |
| February 1973 | 7 | 135 | 88 | 385 ± 71 | 374 ± 74 | 495 ± 85 | 440 ± 66 | 800 | 620 | 8.1 | 1.1 |
| | 8+ | 286 | 158 | 431 ± 89 | 442 ± 83 | 551 ± 85 | 511 ± 63 | 800 | 650 | 22.7 | 8.2 |
| January 1974 | 7 | 372 | 222 | | | 473 ± 85 | 440 ± 68 | 760 | 630 | 6.5 | 1.8 |
| | 8+ | 556 | 369 | | | 540 ± 82 | 503 ± 72 | 750 | 700 | 21.6 | 7.9 |
| December 1976 | 7 | 495 | 356 | 370 ± 73 | 368 ± 70 | 455 ± 84 | 421 ± 64 | 780 | 610 | 5.5 | 0.6 |
| | 8[‡] | 12 | 10 | 487 ± 129 | 390 ± 61 | 598 ± 126 | 482 ± 83 | 750 | 600 | 58.3 | 0 |
| January 1978 | 7 and 8[‡] | 1549 | 1249 | 375 ± 80 | 372 ± 78 | 448 ± 87 | 413 ± 71 | 790 | 760 | 5.3 | 0.8 |
| January 1979 | 7 and 8[‡] | 2046 | 1628 | 370 ± 76 | 370 ± 77 | 436 ± 87 | 404 ± 77 | 790 | 760 | 3.2 | 0.9 |

*N* = 9,927.

[*] Mean score for a random sample of high school juniors and seniors was 368 for males and females.

[†] Mean for juniors and seniors: males, 416; females, 390.

[‡] These rare eighth-graders were accelerated at least 1 year in school grade placement.

**Source:** Benbow and Stanley (1980, p. 1263).

difference among scores is explained by a given variable. Hyde computed various measures of this magnitude and found that even for the highly reliable gender differences, the percentage of variance accounted for by gender was only between 1% and 5%. That is to say, knowing that a person is male or female can improve your guess about how well he or she might perform on a specific cognitive task (such as visuospatial or quantitative) by at most only 5%. Thus generalizations such as "Women should avoid engineering" or "Men make more 'natural' mathematicians" are wholly unwarranted by the existing data.

## Gender Differences in Learning and Cognitive Styles

So far, the evidence reviewed suggests that gender differences in cognition occur for only a few very specific tasks, and even then the gender differences are often small. This in turn suggests we have yet to find evidence that men and women have different basic cognitive capacities, skills, or abilities, except perhaps for certain specific spatial and quantitative tasks.

However, women and men, as well as girls and boys, certainly often appear to teachers and instructors to have differential aptitudes or preferences. More women than men exhibit a "fear of mathematics" and avoid quantitative or analytical courses (such as mathematics, science, logic) when given a choice, beginning in high school (Oakes, 1990). Certainly, it seems to teachers and others who work with students that cognitive gender differences abound. What accounts for the discrepancy between this anecdotal information and the studies reviewed earlier? One possibility is that gender differences arise not so much in basic cognitive resources (capacities, abilities, and the like) but rather in how these resources are used. Recall our earlier discussion of cognitive styles. Perhaps it is in such approaches that women and men differ. In the next two sections, we will review two different but related proposals relevant to this idea.

### Motivation for Cognitive Tasks

Research by psychologist Carol Dweck and her associates (Dweck, 1999; Dweck & Bush, 1976; Dweck, Davidson, Nelson, & Enna, 1978; Dweck, Goetz, & Strauss, 1980) has shown that even in elementary school, boys and girls show differential patterns of *achievement motivation*. This term refers to the ways in which people define and set goals, particularly the goals that are presumed to relate to their own competence (Dweck, 1986). Two major patterns of behavior that appear to affect the ways people approach a broad range of tasks have been identified: a mastery-oriented and a helpless pattern (Dweck, 1999; Dweck & Leggett, 1988).

Children and adults who adopt a mastery orientation set goals to challenge themselves and therefore to increase their competence, understanding, or mastery of something new. These individuals persist when they encounter obstacles or difficulty. Often they also appear to enjoy putting in more effort when it is called for. In contrast, individuals with a helpless orientation fail to set challenging goals and give up rather easily when "the going gets tough."

In a number of studies, Dweck and her colleagues have given older elementary school–age children a number of puzzles or similar problem-solving tasks. Often the tasks are set up to be unsolvable, and children are given "failure feedback"—information that they have failed to complete a particular task correctly. In one study (Dweck & Bush, 1976), children received failure feedback from either a male or a female adult or peer. When the evaluator was an adult, and especially when the adult was female, girls tended to adopt a "helpless" strategy, attributing the cause of their failure to their own inability or lack of competence. Boys, in contrast, were likely in the same circumstances to attribute the failure to the evaluator's "fussiness." It is interesting that when peers administered the failure feedback, boys were much more likely to demonstrate a helpless strategy, and girls were much more likely to attribute problems to their own efforts.

Dweck et al. (1978) reported other findings that might explain why adults' feedback has such different effects on girls and boys. They examined the kind of feedback given to fourth- and fifth-grade girls and boys by classroom teachers. Every instance of feedback to children by the teacher was coded. The experimenters found that when looking at just the positive feedback given, for boys more than 90% of it related to the intellectual quality of their work, but for girls the corresponding figure was less than 80%. The discrepancy for negative feedback was even stronger: For boys, only about a third of the feedback concerned intellectual quality (the rest tended to be about conduct, effort, neatness, or other such things), but well over two thirds of the negative feedback girls received had to do with work-related aspects of their performance.

Dweck and Goetz (1978) concluded that girls, perhaps because of their greater compliance with adult demands, are seen by teachers as expending maximum effort and motivation. Therefore, they come to believe that failure can be attributed only to lack of ability. Boys, in contrast, are more often seen by teachers as lacking in conduct or effort. Thus when boys' performance falls short of expectation, teachers are more likely (in fact, eight times more likely) to attribute the problem to a lack of motivation than to a lack of ability. As a consequence, boys may be inadvertently taught both to be less devastated by criticism (because they receive so much) and to take it less personally (because so much of it has to do with nonintellectual aspects of work and so much is directed to a perceived lack of motivation). Girls, receiving less criticism, have less opportunity to learn how to handle it. Further, adult criticism of girls' work tends to focus on a perceived lack of competence or ability.

Jeff Cadge/Getty Images

*The work of Dweck and others suggests that teachers and other adults who work with children might provide different patterns of feedback to boys and girls about their intellectual abilities.*

In short, girls get the message that failure signals lack of ability (something there is little remedy for); boys, that failure signals a lack of effort (for which the remedy is obvious).

Dweck et al. (1978) tested these ideas in a follow-up study. In it, they had children work on anagram puzzles, and a male experimenter provided failure feedback. Sometimes the feedback was of the sort given by teachers to boys ("You didn't do very well that time—it wasn't neat enough") and sometimes of the sort typically given by teachers to girls ("You didn't do very well that time—you didn't get the word right"). Following these experiences, all children were given another puzzle and were again given negative feedback; then they were asked the following question: "If the man told you that you did not do very well on this puzzle, why do you think that was?" The following choices were provided: "(a) I did not try hard enough. (b) The man was too fussy. (c) I am not very good at it." Children (both girls and boys) in the teacher–girl condition were more than twice as likely to attribute failure to choice (c), a perceived lack of ability. Children (again, both girls and boys) in the teacher–boy condition were far more likely to attribute failure to choice (a), a perceived lack of effort, or choice (b), the "fussiness" of the evaluator.

This research supports the idea that "evaluative feedback given to boys and girls . . . can result directly in girls' greater tendency to view failure feedback as indicative of their level of ability" (Dweck et al., 1978, p. 274). Whether and when these patterns of attribution become stable and generalized is an open question, but one that can bode poorly for women's self-assessment, particularly for tasks perceived to be difficult.

## Connected Learning

Feminist critiques of psychology (Belenky, Clinchy, Goldberger, & Tarule, 1986; Gilligan, 1982; Goldberger, Tarule, Clinchy, & Belenky, 1996) make even stronger claims about the different ways in which men and women approach cognitive tasks. Belenky and collaborators believe that today's predominant culture, historically dominated by males, has come to prize rationality and objectivity over other, equally legitimate, ways of understanding that may be more common among women:

> It is likely that the commonly accepted stereotype of women's thinking as emotional, intuitive, and personalized has contributed to the devaluation of women's minds and contributions, particularly in Western technologically oriented cultures, which value rationalism and objectivity. . . . It is generally assumed that intuitive knowledge is more primitive, therefore less valuable, than so-called objective modes of knowing. (p. 6)

Belenky et al. (1986) obtained their data from interviews of 135 women, some of whom were college students or alumnae, others of whom were members of what the authors called the "invisible colleges"—human service agencies supporting women while they parented their children. Women were described by the investigators as seeking *connected knowing,* in which one discovers "truth" through a conscious process of trying to understand. The kind of understanding sought involves discovery of a personal connection between the individual and the thing, event, person, or concept under consideration. It entails an acceptance and an appreciation for the thing, event, person, or concept on its own terms, within its own framework.

Another style of knowing these authors described, termed *separate knowing,* is perhaps more typical of males and also of women who are socialized in and successful in traditional male environments. This kind of knowing strives for objectivity and rigor, for the learner to "stand apart from" the thing, event, person, or concept being learned or understood. The orientation is toward impersonal rules or standards, and learning involves "mastery of" rather than "engagement with" the information to be learned. Separate knowing, according to Belenky et al. (1986), involves a different intellectual style:

> Separate knowers are tough-minded. They are like doormen at exclusive clubs. They don't want to let anything in unless they are pretty sure it is good. . . . Presented with a proposition, separate knowers immediately look for something wrong—a loophole, factual error, a logical contradiction, the omission of contrary evidence. (p. 104)

Connected knowing, in contrast, "builds on the [learner's] conviction that the most trustworthy knowledge comes from personal experience rather than the pronouncements of authorities. . . . At the heart of these procedures is the capacity for empathy" (pp. 112–113).

If men and women do indeed have different styles of learning and understanding, then perhaps certain ways of processing information also differ in ease or familiarity. For example, mathematics or logic, each with an emphasis on rigor and proof, might seem more attractive to someone with a "separate" way of knowing; more interpretive cognitive tasks, such as understanding a poem or seeking out alternative perceptions, might come more easily to a "connected knower." If styles of knowing vary by gender, then, this could influence the kinds of cognitive tasks men and women find easiest or most appealing.

Little has been done to assess the extent to which the different responses articulated by Belenky et al.'s (1986) female participants are a function of gender as opposed to socioeconomic status, level of education, or other factors. Some work has replicated the finding of gender differences in separate and connected knowing, even among college undergraduates at an elite liberal arts college (Galotti, Clinchy, Ainsworth, Lavin, & Mansfield, 1999; Galotti, Reimer, & Drebus, 2001), but much more remains to be done. More recent work has suggested that a person's "way of knowing" shifts with the context in which the person is interacting, arguing against the idea that ways of knowing are stable tendencies (Ryan & David, 2003). Even if ways of knowing turn out to be largely stable, it is not yet clear whether different ways of knowing predict different kinds of cognitive performance on actual tasks. It remains for future research to examine these important issues.

Proposals from feminist research suggest that cognitive gender differences may not occur on specific tasks but rather in broad approaches to cognition itself. Future work must establish how different the "ways of knowing" are for people of different genders and must investigate how these differences in approach might translate into performance on specific cognitive tasks. It will also be important to assess the effect of gender independent of other demographic variables, such as socioeconomic status, level of education, or cultural heritage.

## SUMMARY

1. Cognition may not always operate the same way for all people. Potential sources of variation in the way people approach the cognitive tasks in their lives include individual differences in cognitive abilities, cognitive styles, and expertise, as well as age and gender.
2. Individuals apparently differ in their cognitive abilities, especially in such things as mental speed, storage capacity, and attention span. Some psychologists equate

these cognitive abilities with intelligence. Other cognitive psychologists do not make this equation but see cognitive abilities as a part of intelligence. Still other psychologists reject the idea that there is one single thing called intelligence.

3. In addition, people can have different cognitive approaches to, or styles in regard to, different tasks. Two of the most investigated cognitive stylistic dimensions are field dependence/independence and reflectivity/impulsivity. Whether the two dimensions are unrelated and the degree to which cognitive styles are modifiable are two important questions for future research.
4. People's expertise can affect the ways in which they approach a cognitive task within their domain of expertise. Experts perceive more distinctions and categorize information differently from the way novices do. Experts can use their domain-related knowledge to chunk information so as to use their memories more effectively.
5. Age-related changes in cognitive processing do not disappear in adolescence; adults of different ages show some systematic differences in cognitive performance. Older adults perform slightly less well than younger adults on tasks of divided attention and working memory, for instance, perhaps because of a general decline in processing speed.
6. Research on gender differences in cognition is very active; therefore, any conclusions must of necessity be tentative. At present, it seems safe to say that with regard to ability, the overall patterns of performance of men and women, boys and girls, are far more similar than different, except for very specific tasks. Many descriptions of cognitive gender differences (for example, in verbal ability) have on close inspection proven either false or at best greatly exaggerated. Other, better established cognitive gender differences (for example, on mental rotation tasks or on certain mathematical tasks, especially algebraic ones) often depend on the age and educational background of the people surveyed and on the particular items used. Even for differences that are very well established, the magnitude of the difference between the average performance for males and the average performance for females is often quite small, accounting for up to only 5% of the total variance.
7. A final set of questions has to do with gender differences in cognitive style or approach. The issue here is whether females and males adopt different strategies in the ways in which they gather, process, or evaluate information. Carol Dweck's work suggests that boys and girls adopt different approaches to cognitive tasks, with girls tending to adopt a more "helpless" outlook, especially in the face of failure. It is not yet clear how girls and boys come to adopt different strategies, although Dweck's work implicates the typical patterns of feedback teachers give to boys and to girls. We can speculate that these kinds of feedback may also come from other agents of socialization—parents, siblings, peers, and others—but the evidence on this question remains to be gathered.

8. Proposals from feminist research suggest that cognitive gender differences may not occur on very specific tasks but rather in broad approaches to cognition itself. Future work must establish how different the "ways of knowing" are for people of different genders and must investigate how these differences in approach might translate into performance on specific cognitive tasks. It will also be important to assess the effect of gender independent of other demographic variables, such as socioeconomic status, level of education, or cultural heritage.

## REVIEW QUESTIONS

1. Discuss the reasons why cognitive psychologists need to know about stable individual and/or gender differences in cognition.
2. What does it mean to assert that there exist stable individual differences in cognitive capacities? Is the assertion synonymous with the belief that there exist stable individual differences in intelligence?
3. Contrast the classical view of intelligence with Gardner's.
4. Discuss the idea of cognitive styles. How does this concept differ from the concepts of intelligence or cognitive abilities?
5. What cautions must be given in interpreting findings on gender differences (or for that matter, any group-related individual differences) in cognition?
6. Explain the logic of a meta-analysis.
7. Discuss the implications of the major findings regarding gender differences in cognitive abilities.
8. How might the work of Dweck and colleagues and Belenky and colleagues bear on the research on gender differences in cognition?

## KEY TERMS

cognitive style
cognitive tempo
effect size (*d*)
experimenter expectancy effects
expert/novice differences
field dependence/field independence (FD/FI)
individual differences
intelligence
meta-analysis
multiple intelligences (MI) theory
need for cognition
reflectivity/impulsivity

## CogLab DEMONSTRATIONS

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

## WEB RESOURCES

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CHAPTER

16

# Cognition in Cross-Cultural Perspective

**Examples of Studies of Cross-Cultural Cognition**
- Cross-Cultural Studies of Perception
- Cross-Cultural Studies of Memory
- Cross-Cultural Studies of Categorization
- Cross-Cultural Studies of Reasoning
- Cross-Cultural Studies of Counting

**Effects of Schooling and Literacy**

**Situated Cognition in Everyday Settings**

Much of the literature covered so far has described the cognitive capacities and processes of people (usually adults, but in some cases children) in the United States or Europe. The implicit assumption has been that the models and theories of cognition developed from such samples are universal—that they apply to and can describe the performance and behavior of people throughout the world. However, research conducted with people from other cultures has often shown this assumption to be problematic, if not in error. In this chapter, we will examine some of this research and consider its implications for the study of cognition.

A number of issues must be discussed in order to consider cross-cultural research. First and foremost, we must come to terms with what makes a **culture.** Certainly, most would agree that people in rural India live in a different culture from people in downtown Baltimore. However, do people in rural New Hampshire experience a culture different from that experienced by people living in Los Angeles?

Triandis (1996) made a forceful argument that psychologists ignore culture at their intellectual peril:

> Almost all the theories and data of contemporary psychology come from Western populations (e.g., Europeans, North Americans, Australians, etc.). Yet about 70% of humans live in non-Western cultures. . . . If psychology is to become a universal discipline it will need both theories and data from the majority of humans. . . . Contemporary psychology is best conceived as a Western indigenous psychology that is a special case of the universal psychology we as contemporary psychologists would like to develop. When the indigenous psychologies are incorporated into a universal framework, we will have a universal psychology. (p. 407)

Psychologists, anthropologists, sociologists, and others have debated the issue of what defines a culture and have come to no widespread and clear-cut resolution to date. Cole and Scribner (1974) noted some of the ingredients of a culture: a distinct language; distinct customs, habits, and modes of dress; and distinct beliefs and philosophies. Other psychologists performing cross-cultural research have also examined factors such as ethnicity and social class in relation to performances on different types of tasks or to attitudes and beliefs (Conway, Schaller, Tweed, & Hallett, 2001; Kagitçibasi & Berry, 1989; Segall, 1986). In fact, Segall (1984) has made the argument that the concept of culture is nothing more than a collection of independent variables such as language, customs, and so on, although others (such as Rohner, 1984) disagree.

Triandis (1996) asserted that dimensions of cultural variation, which he called *cultural syndromes,* can be used in the construction of psychological theories. A cultural syndrome is a "pattern of shared attitudes, beliefs, categorizations, self-definitions, norms, role definitions, and values that is organized around a theme that can be identified among those who speak a particular language, during a specific historical period, and in a definable geographic region" (p. 408). Table 16-1 gives examples of some cultural syndromes Triandis has identified.

The general issue is this: The term *culture* connotes so much that simply finding differences among individuals from one culture to another and attributing those differences to "culture" is a fairly empty statement (Atran, Medin, & Ross, 2005). Instead, the goal is to "unpack" the term and to try to determine which aspects or dimensions of a culture contribute to the differences found. For example, might differences in counting skill be attributed to different uses of number within a culture? Might differences in perception have to do with the typical landscapes encountered by participants of different cultures? What, specifically, within the culture affects the ways in which people acquire, store, and process information?

### Table 16-1 Examples of Cultural Syndromes

| | |
|---|---|
| *Tightness* | In some cultures, there are very many norms that apply across many situations. Minor deviations from the norms are criticized and punished; in other cultures, there are few norms, and only major deviations from norms are criticized. |
| *Cultural Complexity* | The number of different cultural elements, such as role definitions, can be large or small (e.g., about 20 jobs among hunters and gatherers versus 250,000 types of jobs in information societies). |
| *Active-Passive* | This syndrome . . . includes a number of active (e.g., competition, action, and self-fulfillment) and passive (e.g., reflective thought, leave the initiative to others, and cooperation) elements. |
| *Honor* | This pattern is a rather narrow syndrome, focused on the concept of honor. It emerges in environments in which property is mobile and to protect it individuals have to appear fierce so that outsiders will not dare to try to take it from them. It includes beliefs, attitudes, norms, values, and behaviors (e.g., hypersensitivity to affronts) that favor the use of aggression for self-protection, to defend one's honor, and to socialize children so that they will react when challenged. |
| *Collectivism* | In some cultures the self is defined as an aspect of a collective (e.g., family or tribe); personal goals are subordinated to the goals of this collective; norms, duties, and obligations regulate most social behavior; taking into account the needs of others in the regulation of social behavior is widely practiced. |
| *Individualism* | The self is defined as independent and autonomous from collectives. Personal goals are given priority over the goals of collectives. Social behavior is shaped by attitudes and perceived enjoyable consequences. The perceived profits and loss from a social behavior are computed, and when a relationship is too costly it is dropped. |
| *Vertical and Horizontal Relationships* | In some cultures hierarchy is very important, and in-group authorities determine most social behavior. In other cultures social behavior is more egalitarian. |

Source: Excerpted from Triandis (1996, pp. 408–409).

Bovet's (1974) research, for example, addressed these questions by comparing the performance of Algerian and Genevan children and adults on Piagetian tasks of cognitive development. Bovet found some unusual patterns of results among her Algerian participants that she was able to relate to specific features of the Algerian culture. For example, Algerian children had a difficult time with the conservation of quantities. Bovet speculated that some of their difficulty reflected their everyday environment and customs:

> A further point to be mentioned is that eating and cooking utensils (bowls, glasses, plates) of the particular environment studied were of all shapes and sizes, which makes it somewhat difficult to make any comparisons of dimensions. Furthermore, the way of serving food at table was for each person to help from a communal dish, rather than for one person to share it out amongst those present; no comparison of the size of the portions takes place. Finally, the attitude of the mother who does not use any measuring instrument, but "knows" how much to use by means of intuitive approximations and estimations, may have some influence on the child's attitude. Thus, adult modes of thought can influence the development of notions of conservation of quantity in the child by means of familiar types of activities, in which the child participates, even if only as spectator. (p. 331)

Bovet (1974) asserts that aspects of the culture, physical (the shapes and dimensions of eating utensils) as well as behavioral (the practices surrounding the serving of food), guide and constrain the assumptions and questions children naturally have about quantities. Contrast her description of Algerian culture with your impressions of middle-class North American culture: Dinner tables are set such that everyone has the same kind of glass, spoon, plate, and so on. A parent serves each child with roughly the same serving size (perhaps affected by the age or size of the child). Disputes about who "got more" (of, say, an appealing dessert) are common. All these factors might help, in subtle ways, to focus attention on quantities and how quantities relate to such things as container shape and perceptual appearance. This focus, in turn, might help performance on later tests of conservation. Of course, these assertions warrant more rigorous testing before we can accept them. Other aspects of the culture might produce the effect; without empirical testing, we can't be sure.

More recently, social psychologist Richard Nisbett and his colleagues have been investigating differences in cognitive processing by East Asian residents (for example, of Japan, China, Korea) and comparing this to cognitive processing of western European and North American (primarily U.S.) residents. These researchers hold that East Asians typically process information more holistically and more contextually, whereas Westerners process information more analytically (Ji, Peng, & Nisbett, 2000; Nisbett & Norenzayan, 2002; Nisbett, Peng, Choi, & Norenzayan, 2001).

A fundamental question raised by cross-cultural research is the degree to which practices, beliefs, competences, and capacities are *culturally relative* or *culturally universal*. To assert that a cognitive process is culturally relative is to assert that the process is specific to a particular culture or set of cultures (Poortinga & Malpass, 1986). For example, the ability to form hierarchically

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*According to Bovet, even an ordinary setting, such as the dinner table, can affect certain cognitive processing, such as concepts of measurement.*

organized categories (for example, poodles are dogs, which are mammals, which are animals, which are living things) may be much more relevant to people in some cultures than in others (Greenfield, 2005). **Cultural universality,** by contrast, refers to phenomena believed common to humankind, such as the use of language.

The answer to this question profoundly affects the way research questions are framed. If, for instance, a process, capacity, or strategy is assumed to be universal, then cross-cultural questions about it are likely to ask how cultural factors influence and shape it. The assumption here is that the process, capacity, or strategy exists in all cultures but that culture (or some aspect of culture) can facilitate, hinder, or otherwise alter the way it is expressed.

In contrast, people who hold a position of **cultural relativism,** especially radical cultural relativism (Berry, 1981, 1984), would not assume that the process, capacity, or strategy is necessarily present in all cultures. Moreover, they would be less likely to view culture as the sum of several independent factors. Instead, these researchers believe that culture is a kind of Gestalt that cannot be broken into pieces. Certain concepts, processes, capacities, and the like are thus relevant to, and therefore found in, only certain cultures. The kinds of theories and explanations of cognition offered are therefore necessarily different for all (or at least many) cultures.

Cross-cultural researchers face many methodological challenges that do not play as large a role in the research programs of researchers who operate strictly within one culture (such as most of the work described in Chapters 3 through 15). You may recall from introductory psychology that a true experiment involves (a) random assignment of participants to experimental conditions, (b) control over experimental treatments (that is, manipulation of independent variables), and (c) control over other confounding factors or events. Any experimenter has a difficult (if not impossible) task in achieving such control, but a cross-cultural researcher, in principle, can never achieve the first criterion (people cannot be randomly assigned to a culture either practically or ethically) and can probably never in reality achieve the second or third. After all, especially if certain tasks are more relevant to some cultures than others, it is nearly impossible to choose experimental tasks (such as memory tests and problem-solving tests) that are equally difficult and familiar, and equally a good measure of the aspect of behavior or ability under study, for people from different cultures (Malpass & Poortinga, 1986). For a variety of reasons unrelated to cognitive abilities, people from cultures where the task is more familiar might outperform people from cultures where the task is less familiar. Perhaps people from the former culture have had more practice with the task, or feel more comfortable with the task, or enjoy the task more. I will provide specific illustrations of this point.

By the way, you might have noticed that the inability to randomly assign people to cultures is a problem equivalent to the one faced by researchers studying gender, developmental, or other individual differences (Conway et al., 2001). So-called participant variables, such as age, gender, culture, and ethnic origin, are variables that a researcher cannot assign; this makes interpretation of experimental results all the more tricky.

Another problem in conducting cross-cultural research is that individuals within a culture may not take any note of or evaluate that culture (Kitayama, 2002). Cultural practices, such as daily routines, rituals, practices, styles of dress, and mannerisms, may be both tacit and implicit—widely shared within the culture and hence frequently unnoticed or regarded as unremarkable. As Kitayama put it, "What culture is to humans, water is to fish" (p. 90).

In the last section of the chapter, we will examine research in the cross-cultural tradition carried out in the United States. Specifically, we will look at how people's performance works on everyday (that is, nonlaboratory, and often nonschool) cognitive tasks. One important question will serve as our focus: How well do theories and models of cognition, such as those described in earlier chapters, account for cognition "in the real world"? Much of the work reviewed in this chapter demonstrates that people's performance often displays *context sensitivity;* that is, it varies according to the task, the instructions, or other features of the environment.

## ■ EXAMPLES OF STUDIES OF CROSS-CULTURAL COGNITION

In this section, we will review a selection of cross-cultural cognition studies. As in the two previous chapters, it is impossible to examine each facet of human cognition cross-culturally. Instead, we will examine a very small sample of studies of cognitive capacities and processes from a cross-cultural point of view.

### Cross-Cultural Studies of Perception

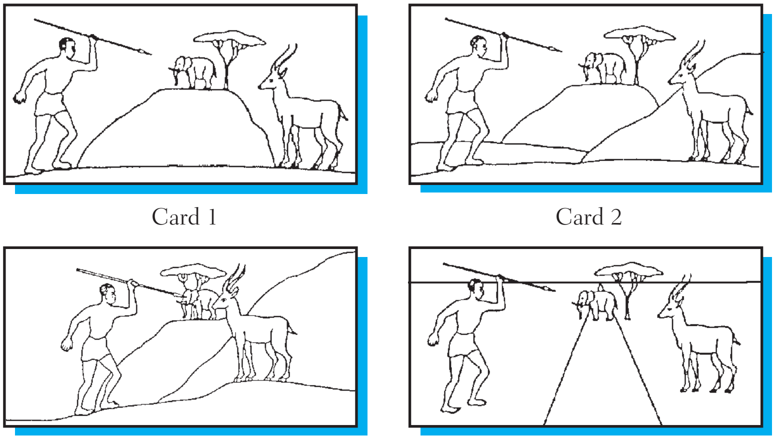
You may recall from Chapter 3 that the term *perception* refers to the interpretation of sensory stimuli—for example, using the information from your retinal image to see an object against a background, or recognizing the furry creature meandering toward you as your cat. Because our perceptions typically occur quickly and effortlessly, it is tempting (but wrong, for reasons we reviewed in Chapter 3) to conclude that perception is a built-in, hard-wired consequence of the way our sensory systems work. However, some landmark studies from cross-cultural psychology have directly challenged this assumption, showing that, quite literally, people from different cultures often "see things" quite differently. What follows below are good illustrations of the kind of top-down processing we talked about in Chapter 3.

### Picture Perception

Studies by Hudson (1960, 1967) demonstrated that people from different cultures frequently do not see eye to eye. Hudson began with the intuition that Bantu workers in South African mines and factories seemed to have difficulty interpreting posters and films. To investigate why, he presented a variety of South Africans (both black and white, schooled and unschooled) with pictures such as those shown in Figure 16-1. Notice that all the pictures depict an elephant, an antelope, a tree, and a man holding a spear. The cards differ in the depth cues presented. Card 1 uses object size (objects farther away are rendered smaller). Cards 2 and 3 also use superposition (nearer objects partially occlude farther objects). Card 4 uses all these cues, and in addition, some cues of linear perspective (lines that are parallel appear to meet in the distance; other outlines or contours are scaled to fit in this framework). Participants were asked to describe what they saw, what they thought the figures in the pictures were doing, and which pairs of figures were closest to each other.

**FIGURE 16-1** ■ *Stimuli from Hudson (1960).*

**SOURCE:** Hudson (1960, p. 186).



Card 1

Card 2

Card 3

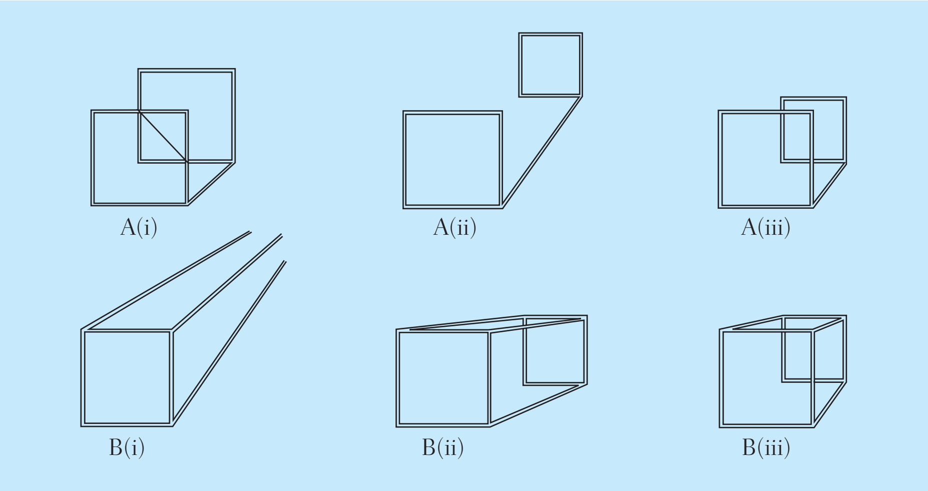
Card 4

Results showed that participants attending school typically came to a three-dimensional interpretation of the pictures (for example, seeing the man aiming the spear at the antelope, and not the elephant; seeing the elephant as far away rather than very small). However, nonliterate workers, both black and white, typically “saw” the pictures two-dimensionally. Hudson (1960) argued that the cause of perceiving pictures three-dimensionally is not schooling per se, but rather informal instruction and habitual exposure to pictures. He believed that such factors as exposure to pictures, photographs, and other illustrations in books and magazines available in the home provide a great deal of crucial, informal practice in "pictorial literacy." His speculation was based on the observation that schools provide little formal instruction in interpreting pictures, coupled with the observation that even the schooled black workers had greater difficulty coming to three-dimensional pictorial interpretations.

Deregowski (1968), studying children and adult workers in Zambia, Central Africa, considered a different possibility. He wondered whether cross-cultural differences in pictorial perception really existed or whether some feature of Hudson's tasks caused participants to respond as if they couldn't interpret the pictures three-dimensionally. In one study, he gave participants two tasks: a version of the Hudson task and a task requiring them to make models from pictured depictions (such as those shown in Figure 16-2) out of sticks.

**FIGURE 16-2** ■ *Stimuli from Deregowski (1968).*

**SOURCE:** Deregowski (1968, p. 197).



Deregowski found that although more than 80% of the participants failed to perceive the Hudson pictures three-dimensionally, more than half constructed three- rather than two-dimensional models. Deregowski (1980) argued, among other things, that perhaps his task and Hudson's differed in difficulty, with Hudson's requiring a more demanding response. For instance, perhaps the building task provides more guidance for the visual inspection of the picture, thus providing more cues to participants as to the "correct" interpretations.

Cole and Scribner (1974) concluded from these and other studies that it is too simplistic to conclude that people either can or cannot perceive pictures three-dimensionally. The issue, they argued, is when and how people come to interpret a two-dimensional stimulus as having depth. Perhaps the content of the pictures (depictions of people and animals and depictions of abstract geometric forms) also influences perception. Perhaps the mode of response (answering a question, building a model) influences the way people perceive pictures. Whatever the reasons, this work suggested that the ways in which people view and interpret two-dimensional pictures depicting three-dimensional scenes are not necessarily the same from culture to culture.

This point was amplified and extended in a study by Liddell (1997). She showed South African children in grades 1, 2, and 3 various color pictures of people and scenes of African origin. Children were asked to examine pictures and to "tell [the tester] what you see in the picture." These commentaries, which were probed for completeness by familiar testers, were later coded for the number of labels a child provided (for example, "That's a flower," "That's a hat"), the number of links a child made between items in the picture (for example, "The table is in front of the lady"), and the number of narratives or interpretations of the picture the child made (such as "The mother is putting the child to bed").

To the total six-picture series given to each child, children averaged 65 labels, 23 links, and 3 narratives. In other words, rather than "interpreting" the pictures, these South African children tended instead to provide factual, even disembodied, pieces of information about them. Moreover, the tendency to provide interpretations *decreased* as a function of years of schooling, with grade 3 children providing fewer than grade 1 or 2 children. Liddell contrasted this finding with one obtained from a sample of British children, who showed increases in narratives as a function of years of schooling. She suggested that the explanation for the difference may lie in the South African system of elementary education, which emphasizes factual and descriptive lessons (as opposed to open-ended or creative ones). Alternatively (or additionally), maybe the paucity of picture books and early readers in most rural African homes precludes these children's complete acquisition of learning to decode or interpret pictures.

Another recent study of photograph perception also makes some very interesting points about cross-cultural differences in perception. Miyamoto, Nisbett, and Masuda (2006) began by taking photographs in three U.S. cities of various sizes (New York; Ann Arbor, Michigan; Chelsea, Michigan) along with three comparable cities in Japan (Tokyo, Hikone, Torahime). The authors went to schools, post offices, and hotels in each city and took photographs from the streets surrounding the buildings. Sample photos are presented in Figure 16-3.

The authors then had both Japanese and American participants (college students) rate each photograph on a number of dimensions, including the

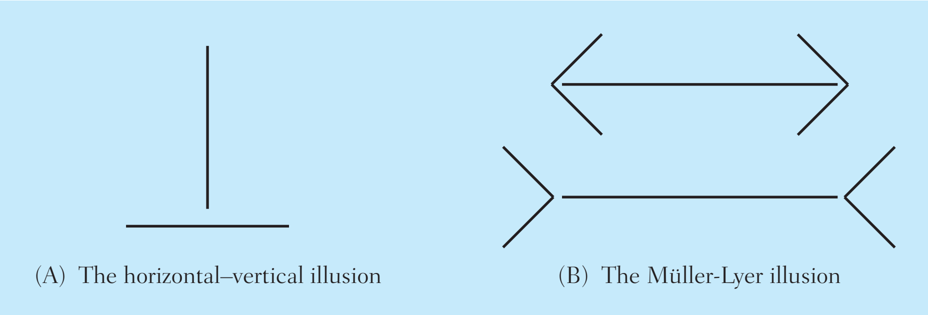
Images not available due to copyright restrictions

number of objects in each photograph, the degree to which the photograph seemed chaotic or organized, how ambiguous or clear the boundaries between objects were. They also created objective measures of the scenes, using computerized image recognition software. Their results showed that the photographs taken in Japan were more ambiguous and contained more elements (objects) than did American ones. They speculate that Japanese scenes may encourage more perception of context than do American scenes. This in turn could explain why, for example, in another of their studies, their American participants in a change blindness task (see Chapter 3) noticed more changes in the focal objects, whereas Japanese participants were more sensitive to changes in "background" or contextual objects (Masuda & Nisbett, 2006).

### Visual Illusions

Other cross-cultural studies of perception have centered on visual illusions, such as those depicted in Figure 16-4. Rivers (1905) studied aspects of visual perception of people from the Torres Straits (Papuans from New Guinea) along with the Todas, people from southern India. Rivers reported that relative to Western samples, the people he worked with were more prone to the horizontal–vertical illusion but less prone to the Müller-Lyer illusion.

**FIGURE 16-4** ■ *Some visual illusions studied cross-culturally.*


(A) The horizontal–vertical illusion

(B) The Müller-Lyer illusion

Segall, Campbell, and Herskovits (1966) followed up on this observation, conducting a now classic study. In it, they used the Müller-Lyer and the horizontal–vertical illusions (refer to Figure 16-4) and worked with approximately 2000 people from 14 African and Philippine locations and the United States. The investigators' hypothesis was that people's previous experience would affect their susceptibility to the illusions. In particular, Segall and colleagues believed that people who came from carpentered environments—characterized by wood or other materials arranged in straight lines, rectangular shapes, and other such geometric relationships—would be relatively more susceptible to the Müller-Lyer illusion. The idea here was that carpentered environments provide the people who live in them with a great deal of practice seeing rectangular shapes (boards, houses, windows) and therefore certain angles and junctions. The Müller-Lyer illusion taps into this experience as follows:

> Among persons raised in a carpentered world there would be a tendency to perceive the Müller-Lyer figure . . . as a representation of three-dimensional objects extended in space. In this instance the two main parts of the drawing represent

> two objects. On the [top of Figure 16-4(B)], for example, if the horizontal segment were perceived as the representation of the edge of a box, it would be a front edge; while on the [bottom], if the horizontal segment were perceived as the edge of another box, it would be the back edge along the inside of the box. Hence, the [top] horizontal would "have to be" shorter than the drawing makes it out, and the [bottom] horizontal would "have to be" longer. (Segall et al., 1966, pp. 85–86)

This argument is based on one offered by the psychologist Egon Brunswik (1956): People interpret cues in any situation according to the ways in which they have interpreted such cues in the past. People do this because in the past they have typically been correct in the way they have interpreted these cues. However, in certain situations, cues can be misleading and can cause people to make false interpretations.

Using analogous reasoning, Segall et al. (1966) predicted that people from cultures where the horizon is a part of the everyday landscape (such as desert or plains dwellers) would be more susceptible to the horizontal–vertical illusion than would people (such as jungle dwellers) from cultures where the environment does not afford opportunities to view vast distances.

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*Segall and colleagues predicted that people from cultures in which the horizon figures in the landscape will show increased susceptibility to the horizontal–vertical illusion.*

Segall et al. (1966) explained the task carefully to all participants, taking many methodological precautions to make sure they understood each task and had opportunities to respond to several versions of each illusion. On each trial, participants were presented with a stimulus pair containing two lines (sometimes consisting of illusions, sometimes consisting of other pairs of lines that produce no illusion) and had to indicate which line was longer. In general, the results confirmed the predictions just described, although both illusions were present in all cultures to a greater or a lesser degree. Despite some later disagreements over the findings by other investigators (see Deregowski, 1980, 1989, for reviews), Segall (1979) maintained that

> people perceive in ways that are shaped by the inferences they have learned to make in order to function most effectively in the particular ecological settings in which they live. The generalization that we can derive . . . is that we learn to perceive in the ways that we need to perceive. In that sense, environment and culture shape our perceptual habits. (p. 93)

Notice that the issue being discussed has to do with perception, how people interpret their sensory information, and not sensation, the acquisition of information. That is, no one claims there are cross-cultural differences in the way the visual (or auditory or olfactory) system works, simply in the stages of cognitive processing that follow the initial acquisition of the information. However, the claim is made that culture affects the way people interpret sensory information—that is, create meaningful interpretations of what they see.

## Cross-Cultural Studies of Memory

Like perception, memory is widely regarded as a process central to almost every other form of cognition. Clearly, all people need a means of storing some of the information they encounter for possible later use. Thus it seems reasonable to believe that memory should show many commonalities across cultures. In this section, we will examine some of the work on memory carried out with people of non-Western cultures.

### Free Recall

Given the assumptions just stated, results from studies carried out with the Kpelle people of Liberia, Africa, were surprising (Cole, Gay, Glick, & Sharp, 1971). As one part of a long series of studies on Kpelle cognition, Cole et al. administered a free-recall task. They read participants a list of nouns (all demonstrated to refer to familiar objects). One set of lists (see Table 16-2) consisted of items that "clustered" into different categories (such as tools, articles of clothing); another set consisted of the same number and types of items but had

### Table 16-2 Stimuli Used by Cole et al. (1971)

| *Clusterable* | *Nonclusterable* |
|---|---|
| Plate | Bottle |
| Calabash | Nickel |
| Pot | Chicken feather |
| Pan | Box |
| Cup | Battery |
| | Animal horn |
| Potato | Stone |
| Onion | Book |
| Banana | Candle |
| Orange | Cotton |
| Coconut | Hard mat |
| | Rope |
| Cutlass | Nail |
| Hoe | Cigarette |
| Knife | Stick |
| File | Grass |
| Hammer | Pot |
| | Knife |
| Trousers | Orange |
| Singlet | Shirt |
| Headtie | |
| Shirt | |
| Hat | |

**Source:** Cole and Scribner (1974, p. 127).

no apparent clusters. Previous work using educated residents of the United States had shown that people's free-recall performance is enhanced when they are given clustered lists, relative to nonclustered lists, especially when the items are presented in blocks, with all items from the same category presented together (Bousfield, 1953; Cofer, 1967).

Kpelle children (ranging in age from 6 to 14) and adults participated. Of the children, some were in school (first through fourth grades) and some were not; all the adults were schooled. The performance of the participants was compared with that of white, middle-class children from southern California.

Cole and colleagues found large age differences in their American sample, with older children recalling far more of the words on each list than younger children. Kpelle participants, however, showed only slight age differences. Moreover, the schooled Kpelles did not outperform the nonschooled Kpelles by much of a margin. Although the clusterable lists were easier for all Kpelle and American samples, only the American participants displayed much clustering in their free recall. That is, regardless of how the items from the clusterable lists were presented, American children, especially those 10 years and older, were more likely to recall all the tools, then all the foods, and so on. The Kpelle participants, by contrast, were quite unlikely to do so.

It appeared, at first, as if the Kpelle had memory systems that worked differently from those of Americans. However, Cole et al. followed up this work by testing a number of rival hypotheses. Perhaps, for example, the Kpelle did not understand the task. Perhaps they were not very interested in the task and therefore did not try very hard. Perhaps the cues provided weren't clear enough. In a number of studies, the investigators gathered evidence against each of these.

In one series of studies, Cole et al. (1971) demonstrated that when the Kpelle were cued to recall items by category (for example, at the time of recall only, the experimenter said something like "Tell me all the clothing you remember. [S. responds.] Okay, now tell me all the tools you remember . . ."), their performance improved dramatically. This result (along with several others we don't have space to review) suggested to Cole and Scribner (1974) that although the Kpelle may perform differently on a memory task, there is little evidence to support the view that memory systems function in ways differing qualitatively from the ways in which American or western European people's memory systems do. In particular, Cole and Scribner argued,

> It appears that the cultural difference in memory performance tapped in the free-recall studies rests upon the fact that the more sophisticated (highly educated) subjects respond to the task by searching for and imposing a structure upon which to base their recall. Noneducated subjects are not likely to engage in such structure-imposing activity. When they do, or when the task itself gives structure to the material, cultural differences in performance are greatly reduced or eliminated. (p. 139)

We will return later to the effects of **schooling,** or years of formal education, particularly in Western-type schools, on cognition.

### Visuospatial Memory

One criticism often raised about exporting traditional, laboratory-based experiments to other cultures is that the tasks themselves vary in familiarity, importance, and general level of interest to people from different cultures. If the charge is true, it raises serious problems for any cross-cultural research comparing the performance of people from different cultures on the same task. If experimental tasks are not closely derived from tasks that people normally engage in during their daily lives, people's performance will not be particularly informative with regard to their real abilities.

Many investigators, taking the criticism seriously, have tried to design studies that closely model real-life tasks. In one such study, Kearins (1981), studying visuospatial memory in desert Australian Aboriginal children and adolescents, presented participants with tasks in which they viewed arrays of objects for 30 seconds and then, after the objects were scrambled, reconstructed the arrays. Kearins's rationale was this: Traditional desert living requires a great deal of movement among widely spaced sites, many of which are "visually unremarkable." For various reasons having to do with unpredictable rainfall and the requirements of hunting and other food gathering, the routes between sites are rarely duplicated exactly. Presumably, this requires kinds of spatial knowledge other than route knowledge. One possibility is greater ability to remember spatial relationships.

> Memory for a single environmental feature would be unlikely to have been a reliable identifier of any particular spot, both because outstanding features are rare in this region of many recurring features, and because of the need for approach from any direction. But particular spatial relationships between several features could uniquely specify a location, more or less regardless of orientation. Accurate memory for such relationships is thus likely to have been of considerable value both in movement between water sources and in daily foraging movements from a base camp. (p. 438)

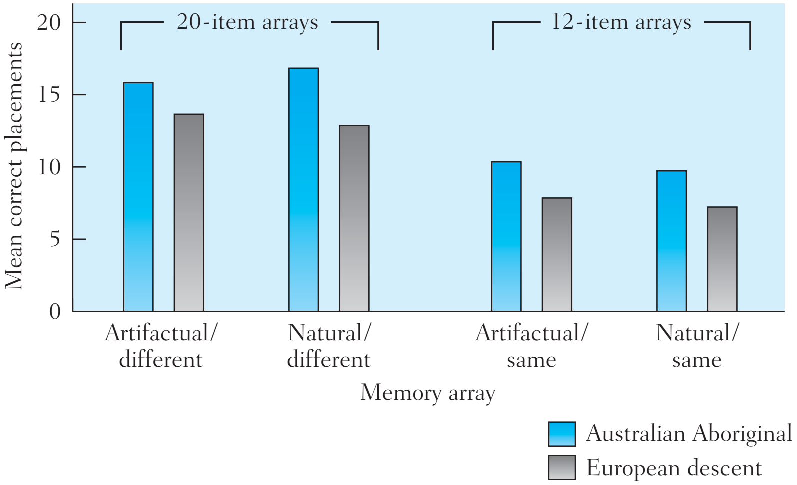
Kearins (1981) presented both Aboriginal and white Australian children with four conditions. In each one, they saw a collection of 20 familiar objects. In two of the conditions, the objects were human-made artifacts (such as a knife or a thimble); in the other two, the objects were naturally occurring objects (such as a feather or a rock). In two of the conditions, all the objects were of the same type (such as all rocks or all bottles); in the other two, they were of different types (such as a knife, an eraser, a thimble). Testing took place on benches in playgrounds or under trees, and care was taken to minimize the "testlike" nature of the task. Children viewed each array for 30 seconds, then closed their eyes while the objects were jumbled in a heap, and then were asked to reconstruct the array with no time limit.

Results, shown in Figure 16-5, revealed that Aboriginal adolescents outperformed their white age-mates in every condition. Kearins commented that the task seemed almost too easy for the Aboriginal children: A significant portion (ranging from 14% to 54% in different conditions, compared to an average of 4.5% for the white children) made no errors.

Observation of the Aboriginal participants revealed that they tended to sit very still while viewing arrays and did not show any evidence of rehearsal. White children and adolescents were much more likely to move around in their seats, to pick up objects, and to "mutter." In the reconstruction phase, Aboriginal children placed objects at a steady, deliberate pace and made few changes

**FIGURE 16-5** ■ *Results from Kearins (1981).*

**SOURCE:** Kearins (1981, p. 441).



as they worked. White Australian children began the reconstruction phase "in great haste" and subsequently made many changes in where the objects were placed. Kearins believed the Aboriginal children were using a visual strategy; white children, a verbal strategy. When asked how they were performing the task, Aboriginal children tended to shrug or to say they remembered the "look" of the array; white Australians tended to describe verbal rehearsal strategies at length.

Kearins (1981) took the data from this and other experiments as supporting her idea that culture can impose "environmental pressure" selectively to enhance certain cognitive skills—in this case, visual rehearsal strategies. She further believed that once a certain skill is established, individuals are more likely to practice it, thus possibly enhancing the skill. Moreover, cognitive (and other) skills and habits useful within a culture are likely to be encouraged by parents and other adults from a child's early years. As a result, certain cognitive abilities become more prevalent and are better performed.

## Cross-Cultural Studies of Categorization

Imagine walking into a room and seeing a number of blocks of various sizes. On one side of each is painted a small, medium, or large circle, square, or triangle that is red or yellow or red-and-yellow striped. Imagine being asked to "put the ones together that go together," a vague instruction that asks you to classify. You can see immediately, I hope, that there are several ways of sorting the blocks:

by painted shape, by block size, or by marking. We could observe your performance, and we could ask two questions about it: What basis do you use to classify the blocks, and how consistent are you in using this basis?

According to psychologist Jerome Bruner (Bruner et al., 1966), the way we carry out classification tasks changes with development. At first, we tend to use perceptual bases for classification, especially color (Olver & Hornsby, 1966). Later, the basis of our sorting (when more meaningful objects, as opposed to blocks, are used) becomes less perceptual and more "deep," as we start to group objects together on the basis of function rather than form. So whereas a young child might group a carrot and a stick in one set and a tomato and a ball in another (paying attention to shape), an older child might be expected to group the two foods and the two artifacts. Moreover, children's ability to sort objects consistently, using whatever basis they choose, also increases with development, as we saw in Chapter 14.

Patricia Greenfield, a collaborator of Bruner's, carried out similar studies with unschooled Wolof children in rural Senegal, West Africa (Greenfield, Reich, & Olver, 1966). Children (ages 6 to 16) saw ten familiar objects, four of which were red, four of which were items of clothing, and four of which were round (some objects had two or more of these properties). They were told to choose the objects that were "alike" and then to say how they were alike.

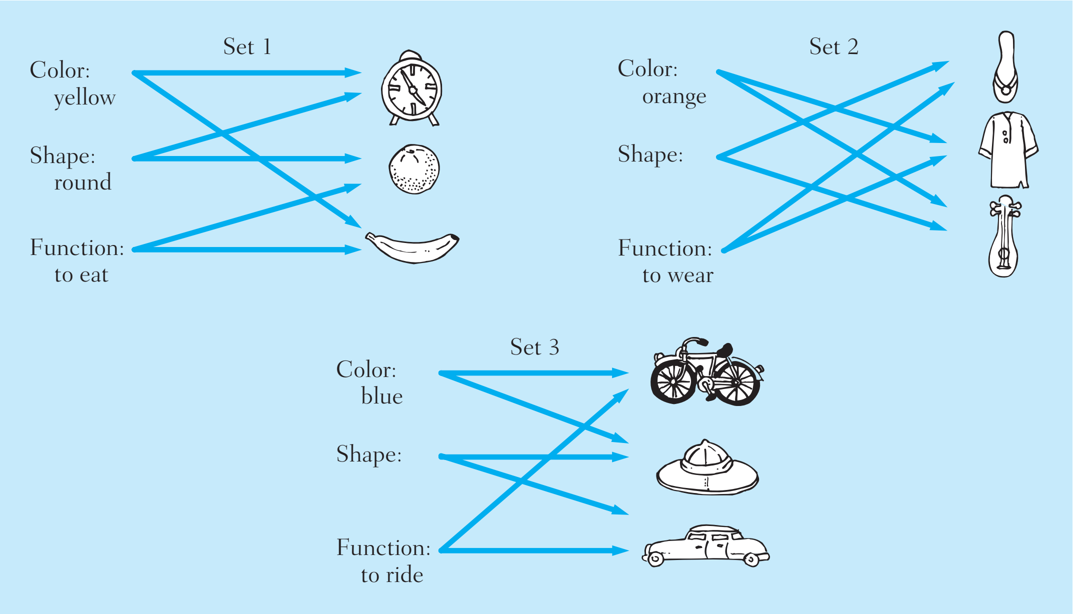
The question was "Did children use any of these bases in a systematic way, selecting all and only the red objects, all and only the round objects, or all and only the articles of clothing?" Most of the Wolof children (typically over 65%) selected items on the basis of color, but they showed great improvement with age in their ability to do so systematically. At age 6 or 7, only about 10% systematically selected all and only the four red objects; at age 9, about 30%; and by age 15, close to 100%.

In a second study with schooled and unschooled Wolof children (ages 6 to 13) and unschooled adults, Greenfield et al. (1966) presented sets of three pictured objects. Within each set, two objects shared a color; two, a shape; and two, a function. Figure 16-6 provides some examples. Participants were asked to show which two of the three objects in each set were "most alike" and to explain why.

Greenfield examined the bases on which children and adults grouped items. Schooling was found to have a very powerful effect. First, unschooled participants had more trouble interpreting the pictures and recognizing the depicted objects, a finding consistent with those reported by Hudson (1960), discussed earlier. Second, children who had attended school were much less likely to use color as a classification basis, and the decrease in preference for color was associated with years of schooling. Conversely, sorting on the basis of form and of function both rose with years of schooling. In fact, the use of either form or function as a basis for sorting was "virtually nonexistent" for

**FIGURE 16-6** ■ *Stimuli used by Greenfield et al. (1966).*

**SOURCE:** Greenfield et al. (1966, p. 290).



unschooled participants (Greenfield et al., 1966, p. 295). In general, the authors concluded that "schooling appears to be the single most powerful factor we have found in the stimulation of abstraction" (p. 315).

Sharp and Cole, working with Mayan people in Yucatán, Mexico, wondered whether a preference for grouping by color necessarily precluded other bases for grouping (Cole & Scribner, 1974). They presented participants (children in the first, third, and sixth grades and adolescents with three or fewer years of school) with cards depicting various geometric figures that varied in color, shape, and number (such as one circle, two circles). After the participants had sorted the cards, the experimenters asked them to re-sort the cards on another dimension. The results showed, first, that the percentage of participants able to sort consistently on the basis of color, shape, or number rose dramatically with years of schooling. Second, the ability to reclassify also depended on schooling: First-graders were almost completely unable to reclassify, and fewer than half of the third-graders and adolescents (with three or fewer years of schooling) could reclassify. Of the sixth-graders, 60% were able to re-sort, using a dimension different from that used in the first sorting.

Irwin and McLaughlin (1970) found another variable that affected performance on this task. They performed a similar experiment, using stimuli like those employed by Sharp and Cole; in another condition, stimuli consisting of eight bowls of rice. Rice was a very familiar commodity to the Mano rice farmers in central Liberia, who were the participants. The bowls of rice differed in type of bowl (large or small) and type of rice (polished or not polished).

Results showed that although unschooled adults were not very able to re-sort either the cards or the bowls, all the participants, including the adults, were much more able to sort the rice than the cards quickly. In a later study, Irwin, Schafer, and Feiden (1974) worked with Mano farmers and American undergraduates. Both groups were given geometric shapes on cards (in one condition) and rice (in another condition) to sort. As expected, the Mano had trouble with the shapes but sorted the rice quite easily. Conversely, the Americans did quite well sorting and re-sorting the shapes but were less adept at noticing all the possible bases for sorting the rice. Taken together with the earlier study, these results suggest that differential exposure to stimuli (presumably as a consequence of cultural setting) can have dramatic effects on even as supposedly basic a cognitive task such as sorting.

Hatano, Siegler, Richards, Inagaki, Stavy, and Wax (1993) extended this line of investigation when they examined concepts of being biologically alive with children from Japan, Israel, and the United States. Although all three countries, in the authors' words, are "highly developed and scientifically advanced," they differ in the ways their dominant cultures regard the relationship of plants to animals.

> Japanese culture includes a belief that plants are much like human beings. This attitude is represented by the Buddhist idea that even a tree or blade of grass has a mind. Many Japanese adults . . . view plants as having feelings and emotions. Similarly, even inanimate entities are sometimes considered to have minds within Japanese folk psychology. (p. 50)

In contrast, "Within Israeli traditions, plants are regarded as very different from humans and other animals in their life status" (p. 50).

Hatano et al. (1993) interviewed kindergartners and second- and fourth-graders in all three countries, asking them about whether people, other animals (a rabbit and a pigeon), plants (a tree and a tulip), and inanimate things (a stone and a chair) had various properties of animacy, such as whether they were alive; had things such as a heart, bones, or a brain; had sensory capacities to feel cold or pain; and could do things such as grow or die. The authors reported several interesting findings. One set concerned the "rules" that individual children seemed to be using. One rule, called the "people, animals, and plants" rule, meant that a child consistently judged these three things as being alive but inanimate things as not being alive. Another rule, the "people and animals" rule, involved judging only people and animals to be alive (not plants or inanimate things). The "all things" rule corresponded to consistent judgments that all things asked about, including the stone and chair, were alive.

**FIGURE 16-7** ■ *Percentage of children who adopted each rule (see text).*

**SOURCE:** Hatano et al. (1993, p. 58).

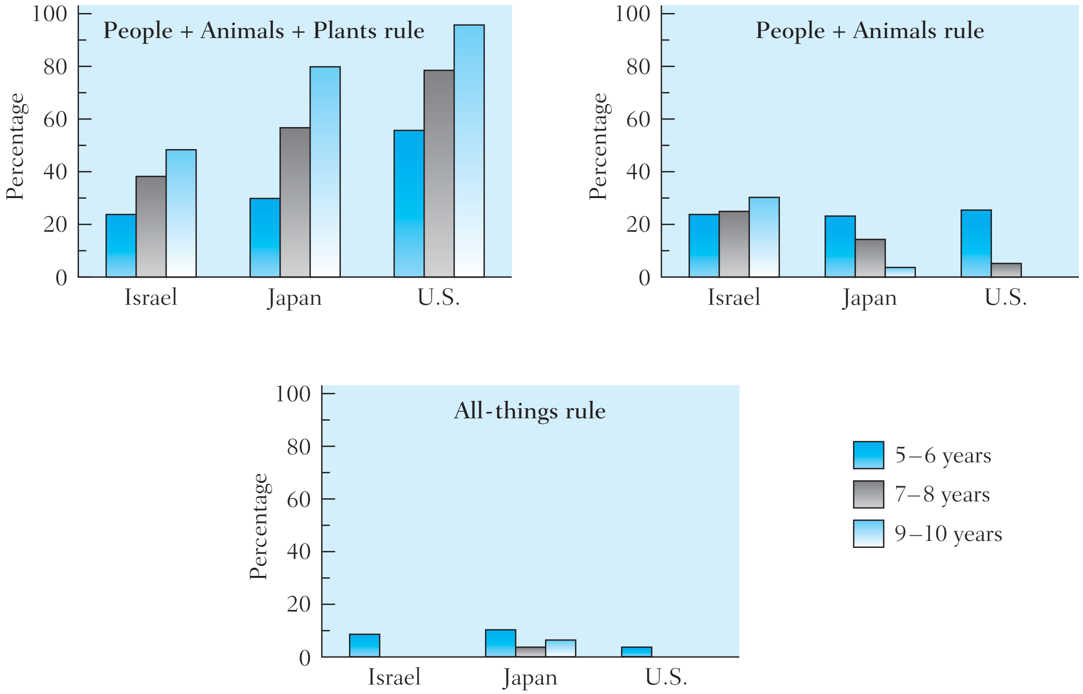


Figure 16-7 presents some of the results. More children in the United States used the "people, animals, and plants" rule, and this pattern held for every age group tested. Children from Israel were more likely than children in either other country to deny that plants were alive (that is, to use the "people and animals" rule). The authors speculated that children's television programming in the United States may account for the apparent superiority of biological knowledge among children from the United States. They argued that various nature shows, magazines, and picture books are more common in the United States than in Japan or Israel and that these may be an influential determinant of children's conceptual knowledge, especially among kindergartners. Of course, this is not the only possible explanation, and it warrants further investigation.

Taken together, the studies reviewed in this section suggest that using familiar materials helps to uncover cognitive competence, a principle discussed originally in Chapter 14. Once again, the results described here provide reasons for caution in interpreting cognitive abilities, especially cross-culturally. People tend to believe there is only one (or only one correct) way of processing information in a cognitive task. The results of the several studies described in this chapter remind us that people may have considerably more flexibility in their cognitive processing and that the ways they approach a task depend on the context, the instructions, and even the stimulus materials.

## Cross-Cultural Studies of Reasoning

We saw in Chapter 12 that formal reasoning involves drawing conclusions based solely on the given information, or premises. Many psychologists and philosophers have assumed that such processing underlies the kinds of reasoning and thinking that occur frequently—that problems such as "All men are mortal; Socrates is a man; (therefore) Socrates is mortal" are basic and therefore rather easy to deal with.

A. R. Luria (1976), a student of the Soviet psychologist Lev Vygotsky, examined how farmers living in Central Asia, some literate and some not, approached such verbal syllogisms. Some of the syllogisms had familiar, practical content but required the participant to apply a familiar principle to a new environment. Here is an example: "Cotton grows where it is hot and humid. England is cold and damp. Can cotton grow there or not?" Another example: "In the Far North, where there is snow, all bears are white. Novaya Zemlya is in the Far North. What color are the bears there?"

The responses to these syllogisms depended on the background of the farmers. Those with no schooling simply refused to deal with the problem, typically responding something like "I don't know; I've seen a black bear, I've never seen any others. . . . Each locality has its own animals; if it's white, they will be white; if it's yellow, they will be yellow," or "How should I know?" (Luria, 1976, pp. 109–110). One respondent, a nonliterate 37-year-old resident of a remote village, summed up the problem: "We always speak only of what we see; we don't talk about what we haven't seen." When the experimenter asked, "But what do my words imply?" and repeated the syllogism, the villager responded, "Well, it's like this: Our tsar isn't like yours, and yours isn't like ours. Your words can be answered only by someone who was there, and if a person wasn't there he can't say anything on the basis of your words" (p. 109).

Nonliterate villagers faced three limitations, according to Luria (1976). First, they had difficulty accepting (even for the sake of argument) initial premises that contradicted their own experience. Often such premises were dismissed and forgotten. Second, nonliterate villagers refused to treat general premises (such as "In the Far North, all bears are white") as truly general. Instead, they treated these statements as descriptions particular to one person's experience and again often ignored the premise in their reasoning. Third, those lacking literacy tended not to see the various premises as parts of a single problem but rather treated all the premises as independent pieces of information.

The farmers who had participated in a literacy program, by contrast, accepted the fact that conclusions could be drawn not just from their own knowledge but from the problem (premises) itself and drew the correct conclusion.

However, looked at from another point of view, these villagers could be seen as reasoning logically, albeit with very different premises. In effect, their argument could be construed as follows: "If I had firsthand knowledge of a black bear, I could answer the question; I don't have firsthand knowledge; therefore, I cannot answer the question." Cole and Scribner (1974) reported similar results with reasoning tasks given to Kpelle tribespeople from Liberia. The following is an example:

> EXPERIMENTER (LOCAL KPELLE MAN): At one time spider went to a feast. He was told to answer this question before he could eat any of the food. The question is: Spider and black deer always eat together. Spider is eating. Is black deer eating?
>
> SUBJECT (VILLAGE ELDER): Were they in the bush?
>
> EXPERIMENTER: Yes.
>
> SUBJECT: Were they eating together?
>
> EXPERIMENTER: Spider and black deer always eat together. Spider is eating. Is black deer eating?
>
> SUBJECT: But I was not there. How can I answer such a question?
>
> EXPERIMENTER: Can't you answer it? Even if you were not there, you can answer it. (Repeats question)
>
> SUBJECT: Oh, oh, black deer is eating.
>
> EXPERIMENTER: What is your reason for saying that black deer is eating?
>
> SUBJECT: The reason is that black deer always walks about all day eating green leaves in the bush. Then he rests for a while and gets up again to eat. (p. 162)

Notice a few things here. First, the participant avoids answering the question, asserting that his lack of personal knowledge or experience prevents him from knowing the answer. His assumption is that questions can be answered based only on personal, firsthand knowledge. When pressed by the experimenter, the participant comes up with a response but again gives reasons that are based on his knowledge rather than on the premises of the syllogism itself. In Henle's (1962) terms, the participant has "failed to accept the logical task," refusing to draw conclusions based on (or based only on) the premises supplied by the experimenter.

Other participants in this study showed different ways of avoiding the task set for them by the experimenter. Some introduced new premises, usually ones that incorporated the participant's personal knowledge, so that a conclusion could be drawn and justified based on this knowledge. Research by Sylvia Scribner suggested that participants appeared to distort the syllogisms in memory, forgetting some premises, and altering others, as this example shows:

> PROBLEM: The chief's brother either gave him a goat or he gave him a chicken. The chief's brother did not give him a goat. Did he give him a chicken?
>
> SUBJECT: Yes. I know he gave it to him.
>
> (Subject is then asked to recall the problem): The chief's brother will give him a goat. If he does not give him a goat, he will give him a chicken.
>
> EXPERIMENTER: What question did I ask?
>
> SUBJECT: You asked me, is the chief's brother going to give him a goat?
>
> EXPERIMENTER: (Reads problem again)
>
> (Subject is asked to recall the problem): Yes. That is what you told me. The chief's brother will give him a goat. If he does not give him a goat, he will give him a chicken.
>
> EXPERIMENTER: What question did I ask you?
>
> SUBJECT: You asked me, the chief's brother will give him a goat. If he does not give him a goat, will he give him a chicken? (Cole & Scribner, 1974, p. 165)

Notice here that the participant does not reproduce all the premises in the problem. On each recall, he omits the second premise, that the chief's brother did not give him a goat. Without this premise, the question cannot be answered, perhaps accounting for the fact that the participant continually has difficulty keeping in mind the question asked.

Apparently, then, one difficulty with syllogistic reasoning with nonliterate people is their inability or unwillingness to "remain within problem boundaries" (Cole & Scribner, 1974, p. 168). Instead, people tend to omit, add, or alter premises so that conclusions can be drawn from personal knowledge.

It is worth pointing out that such errors are not unique to people from nonliterate cultures. As we saw in Chapter 14, young children have difficulty staying "within bounds" when working on a reasoning task. In addition, the tendency to alter, omit, or add premises to a syllogism occurs with adults in the United States as well, especially on difficult problems, as Henle (1962) argued. This in turn suggests that the reasoning of people from other cultures does seem similar in terms of basic processes, and that what is difficult for one culture also seems to be difficult for others. The data also suggest that schooling or literacy improves people's formal reasoning abilities, something we will explore in greater depth later.

However, recent work by Nisbett and his colleagues has suggested that not all cross-cultural differences in reasoning can be explained in terms of exposure to formal schooling. For example, content effects in formal reasoning tasks were found to be greater for Koreans than for Americans (Norenzayan, Choi, & Nisbett, 2002). Chinese and Korean university students used more intuitive strategies of reasoning compared with European American university students, who relied more on formal reasoning strategies (Norenzayan, Smith, Kim, & Nisbett, 2002). Norenzayan and Nisbett (2000) believe this cross-cultural difference in reasoning may be a consequence of a more general cultural difference in holistic (East Asian) versus analytical processing of information, discussed earlier. Nisbett and Norenzayan (2002) offer a possible interpretation of how some of the cross-cultural difference may have evolved:

> The preference for formal logical reasoning prevalent in Western cultures may be only partly the result of the introduction of modern institutions such as industrialization. Other cultural factors that have been historically tied to the Western intellectual tradition, such as adversarial debate, contractual relationships, theoretical science, and formalization of knowledge may account for the development of formal logical reasoning as a rhetorical system central to these activities. (p. 573)

## Cross-Cultural Studies of Counting

One of the most fascinating lines of cross-cultural cognitive research centers on the development of mathematical (usually arithmetical) knowledge and problem solving. If you think about it, the development and use of an arithmetical system is critical for many kinds of everyday activities in almost all cultures: buying, selling, making change, keeping inventories, determining relative amounts, and the like. It is of great interest to note that not all cultures have developed the same systems and to examine the ways in which the systems that exist have evolved.

Let us first examine the arithmetic skill of counting. Work by Rochel Gelman and Randy Gallistel (1978) with preschoolers in the United States demonstrated that even very young children in the United States know a great deal about counting. With small numbers (that is, less than about 5), even 2- and 3-year-olds can count the number of items in a set. But what does it mean to count? Gelman and Gallistel offered this surprisingly complicated definition:

> [Counting] involves the coordinated use of several components: noticing the items in an array one after another; pairing each noticed item with a number name; using a conventional list of number names in the conventional order; and recognizing that the last name used represents the numerosity of the array. (p. 73)

Gelman and her colleagues observed the counting behavior of preschoolers and were able to identify several distinct "principles" of counting. These are described in the following list:

1. *The one-one principle.* Each item in a to-be-counted array is "ticked" in such a way that one and only one distinct "tick" is assigned to each item.
2. *The stable-order principle.* The tags (count words) assigned to each item must be chosen in a repeatable order.
3. *The cardinal principle.* When one is counting an array, the final tag represents the number of items in the set.
4. *The abstraction principle.* Any group of items, whether physical or not, whether of the same type or not, can be counted.
5. *The order-irrelevance principle.* The order of enumeration (that is, which item is tagged "1," which "2," and so on) of items in a set does not affect the number of items in the set or the counting procedure.

A child might have some but not all of these principles at any stage of development. Nonetheless, even if her "counting" behavior doesn't exactly match that of an adult, she can be properly described as "counting" if her behavior shows evidence of honoring at least some of the principles. For example, a child aged 2 years and 6 months counted a plate containing three toy mice as follows: "One, two, six!" Asked by the experimenter to count the mice once again, the child happily complied: "Ya, one, two, six!" (Gelman & Gallistel, 1978, p. 91). This child shows clear evidence of respecting the one-one and the stable-order principles and therefore really is counting, even though she uses a different count-word sequence than adults do.

Cross-cultural work by Geoffrey Saxe (1981; Saxe & Posner, 1983) provides evidence that counting systems vary in different cultures. Saxe reported studies of children in a remote Oksapmin village in Papua New Guinea. Unlike the base-10 system of numbers used in our culture, Saxe found that the Oksapmin developed a body-part counting system with no base structure. Instead, the Oksapmin label 27 distinct body parts on the hands, arms, shoulders, neck, and head. Just as we count on our fingers, the Oksapmin count not only fingers but arm, shoulder, neck, and head locations, looping back and adding prefixes when they need a number larger than 27. Figure 16-8 illustrates the Oksapmin counting system.

One question that arose for Saxe and others was whether the existence of a "baseless" numeration system, as used by the Oksapmin, would change the understanding of certain numeric relations. For example, is a Piagetian number conservation task (see Chapter 14 if you need a review), which relies on understanding the concept of "more" or "less" than, much harder for Oksapmin children than for U.S. children? Saxe (1981) found that although Oksapmin

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children generally develop counting and conservation concepts at later ages, their developmental pattern is quite similar to that of children in the United States. It is interesting that Oksapmin who participate frequently in a newly introduced money economy, which requires more arithmetic computation than does more traditional Oksapmin life, are changing and reorganizing their body-part numeration systems to make computation easier.

A more recent study bears on the issue of the base system and its relation to counting. Miller, Smith, Zhu, and Zhang (1995) asked preschool children from Champaign-Urbana, Illinois, and Beijing, China, to perform a variety of counting tasks. This comparison was interesting because Chinese and English differ in their naming conventions for numbers. Both have distinct and unpredictable names for the digits 1 through 10. That is, you cannot predict from knowing that the numeral 8 is named *eight* that the numeral 9 will be named *nine;* number names up through 10 are unordered.

However, for the second decade of numbers, the two languages diverge. Chinese uses a consistent base-10 system of naming: the name for 11 in Chinese translates literally to "ten one." In English, however, the names for 11 and 12 (*eleven* and *twelve*) do not make clear the relationship of these numbers to the numbers 1 and 2. After the number 20, the two languages name numbers in similar ways, although English throws in a few more twists than Chinese does (making 20 *twenty,* for instance). This led the investigators to predict that Chinese preschoolers would have an easier time learning to count, especially for numbers in the teens.

Children were given various counting tasks. For example, children were asked to count as high as possible and were prompted to continue by the experimenter whenever they stopped. The final number the child reached was regarded as his or her counting level. Figure 16-9 shows the median counting level for preschoolers of different ages. Although 3-year-olds from both countries reach about the same number, Chinese 4- and 5-year-olds can count significantly higher than can their American counterparts.

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The investigators also looked at whether there was a pattern of difference as to where children stopped counting. There were no differences in the percentage of children who could only count to a number below 10: The researchers found that 94% of American children and 92% of Chinese children all could count to this number. However, only 48% of American preschoolers could count to 20, in comparison with 74% of the Chinese preschoolers, a striking difference. This difference did not grow larger in succeeding decades, suggesting that counting breaks down for U.S. children at the place where the languages differ in making clear the base-10 nature of the number system. Miller et al. (1995) argued that such differences play a role in explaining why school-age children in China and Japan have been shown to outperform their same-age counterparts in the United States. Although many shortcomings in arithmetic instruction have been documented in the United States compared with that of some Asian countries (Stevenson et al., 1990), Miller et al. asserted that some of the problem traces back, at least in part, to fundamental differences in understanding the base-10 nature of the number system at the time when children enter school.

Throughout this section, we have seen examples of the ways in which cognitive tasks and performance can differ across different cultures. We have also seen that one important variable affecting a number of different cognitive tasks is schooling. In the next section, we will examine the effects of this variable more closely, trying to isolate just what aspects of schooling produce the effect.

## ■ EFFECTS OF SCHOOLING AND LITERACY

What is it about schooling that apparently produces such widespread changes in cognition? Is it something about the curriculum specifically, or do the changes result from a more global aspect of the context of going to school? These questions are just beginning to be addressed in the cross-cultural study of cognition.

One candidate for the source of schooling effects is **literacy,** the ability to read and write. Many psychological, linguistic, and anthropological scholars believe that literacy has profound effects on society (Scribner & Cole, 1981). One assertion is that literacy changes thought in fundamental ways because it lets the mind expand and grow. Scholars dating back to Plato and Socrates wondered whether written language promoted logical and abstract thinking in a way that oral language does not and cannot (Scribner & Cole, 1981). Goody and Watt (1968) argued, for instance, that disciplines such as history and logic are impossible without written language. Writing a text offers a permanency that oral language does not. This permanency allows people to carry on certain processes that might be impossible otherwise—for example, comparing two sentences to look for implications or inconsistencies, or examining the internal structure or syntax of a sentence.

Lev Vygotsky, a noted Marxist psychologist, argued, as Marx had, that a human being's "nature" was actually the product of his or her interaction with the environment (Vygotsky, 1986). Thus cognitive processes and capabilities are not simply the result of our biological heritage but rather the result of human–environment interaction, which changes and shapes not only the environment but also the nature of our cognition (Scribner & Cole, 1981).

At any given time, the tools available for a task change the ways in which the task is carried out. For example, the invention and availability of word-processing software has changed the ways in which many professors and college students write papers. The World Wide Web has changed the way people acquire and search for information. Vygotsky thought the same principle applied to the existence of written language: It significantly transformed intellectual processes.

The Laboratory of Comparative Human Cognition (1983) described Vygotskian principles of how cultures affect cognition and cognitive development (p. 335). First, cultures "arrange for the occurrence or non-occurrence" of particular problems and problem-solving environments. For example, whether one needs to learn to memorize prayers or pledges depends on whether the culture presents tasks or occasions for which they are recited from memory. If the culture does not require such memorization, then people within that culture have less need to develop strategies and approaches to this task.

Second, the culture determines the frequency with which problems and practices occur. Does recitation take place daily? Weekly? Monthly? Frequency will no doubt affect how often practice with the tasks occurs.

Third, cultures determine which events go together. Does memorization occur with other tasks, such as reading or measuring? It seems likely that the co-occurrence of two tasks provides a different context for each and may therefore affect the way each is carried out.

Last, cultures "regulate the level of difficulty" of tasks within contexts (Laboratory of Comparative Human Cognition, 1983, p. 335). Cultures determine how younger members may approach the memorization task, for example. Cultures also figure out ways of establishing a graded series of tasks that culminate in final

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*Schooling has been shown in many studies to affect performance on a variety of cognitive tasks.*

mastery. A 4-year-old, for example, may start out learning simple rhymes and gradually work up to long prayers or epic poems. The culture determines the path from first to final achievement.

Recall discussion of the work of Alexander Luria (a student of Vygotsky), who worked with farmers in Uzbekistan, a remote part of the former Soviet Union, during the 1930s (Luria, 1976). During that time, collectivization of farming and industrialization were being introduced, and the region experienced profound socioeconomic changes. As part of this social and economic revolution, some of the residents attended literacy programs. Luria compared, on a variety of perceptual, reasoning, and classification tasks, the performance of people who had and had not participated in a literacy program. He found consistent group differences: Nonliterate people were most likely to respond to tasks in a concrete, perceptual, and context-bound manner; the schooled group showed greater ability or propensity to deal with materials more abstractly and conceptually. The schooled group could reason from premises and draw inferences based on something other than their own experience.

One problem in interpreting Luria's (1976) findings is that two related but conceptually independent factors were confounded: literacy and schooling. As Scribner and Cole (1981) noted, schooling and literacy are often related but are not synonymous. In Luria's research, the participants who were literate were also those who had attended schools; the nonliterate participants were unschooled.

What effects might schooling have on cognition? First of all, it is worth noting the somewhat bizarre demands that school itself places on students. School is one of the few places where one person (the teacher) asks other people (the students) to answer questions that she or he already knows the answer to. Think how incongruous this situation would be in other contexts. Imagine someone walking up to you to ask directions to the library. Being a local resident, you know the way and provide a set of directions, such as "Go up two blocks to the light, take a right, then take your first left, go halfway down the block, and you'll see it." Next, your conversation partner tells you your directions are faulty, that there is a simpler way to go. Would you consider this conversation "normal" or "typical"? Only in school-like situations can a teacher pose questions to assess students' knowledge rather than to obtain information. This makes the school context somewhat removed from everyday life.

School differs from everyday contexts in a number of other respects. The subjects taught often make little contact with everyday life; students learning about, say, geography or history may never have the chance to experience the phenomena being discussed. Some of the subjects taught are abstract (such as arithmetic and geometry) and make little direct appearance in day-to-day living.

The motivation to complete a task—for example, learning a spelling list—is not intrinsic to the task itself in the way that motivation is for an everyday task—for example, learning to ride a bike. In the latter case, you learn because the task itself is important to you; in the former case, students often learn because the teacher or parent tells them to. Bruner (1966) has argued that schooling therefore provides practice in thinking about abstract topics in a decontextualized way—that is, removed from the present context of here and now.

> The important thing about the school . . . is that it is removed from immediate context of socially relevant action. This very disengagement makes learning an act in itself. . . . Verbal understanding, the ability to say it and to enumerate instances, becomes the criterion of learning. (pp. 62–63)

Scribner and Cole (1981) carried out a series of studies to disentangle the effects of literacy from the effects of schooling. They worked with the Vai people in Liberia, West Africa, during the 1970s. The Vai are an interesting people to study because they invented their own writing system, called Vai script, that they use for many commercial and personal transactions. Vai script is taught not in school but in the home. Although only about 7% of the entire population was literate in Vai script at the time of the study, it was the most common written language known by adult males: 20% were literate in Vai script; 16% in Arabic (acquired mostly in the context of learning the Qur'an); and 6% in English, the official language of schools and government.

Interviews were held with 650 people, all aged 15 or older. In addition to a lengthy autobiographical questionnaire (regarding demographic information, schooling and literacy status, family schooling and literacy status, occupation, and the like), all respondents participated in an hour-long session in which various cognitive tasks were administered. Included in these were sorting tasks (stimuli used included both geometric figures and familiar objects), memory tasks (such as recalling the names of objects used in the sorting tasks), a logic task (presenting syllogisms, such as those described earlier), and a task of linguistic awareness (such as asking whether the names of the objects "sun" and "moon" could be switched, and what the consequences of such a switch would be). For some tasks, respondents were asked to provide verbal explanations, which were later scored.

The participants were divided into seven groups. The first six included only men 15 and older: nonliterate men; men who were literate in Vai script only; men literate in Arabic only; men literate in both Arabic and Vai; men who had attended some school and were literate in English, Arabic, and Vai; and men who had attended 10 years or more of school. The seventh group consisted of nonliterate women 15 and older (the data from 11 literate Vai women were not reported, presumably because the women were quite atypical in their literacy).

The general design called for comparisons of nonliterates, Vai script literates, and schooled groups. The results, some of which are summarized in Table 16-3,

## **Table 16-3** Results of Scribner and Cole (1981)

| *Tasks and Measures* | *Nonliterate Men* | *Vai Script Monoliterate* | *Arabic Monoliterate* | *Vai Arabic Biliterate* | *English Schooled* | *Grade 10+* | *Nonliterate Women* |
|---|---|---|---|---|---|---|---|
| Geometric sorting (number dimensions sorted out of 3) | 1.6 | 2.0 | 2.0 | 1.9 | 1.7 | 1.9 | 1.7 |
| Verbal explanation (max score = 12) | 5.3 | 5.1 | 5.8 | 5.6 | 5.6 | 9.3 | 4.9 |
| Classification (max score = 6) | 3.4 | 3.5 | 3.0 | 3.5 | 3.8 | 3.9 | 3.4 |
| Verbal explanation (max score = 42) | 31.5 | 31.2 | 29.0 | 29.5 | 32.5 | 34.6 | 30.5 |
| Memory (number recalled, max = 24) | 16.2 | 16.0 | 16.2 | 16.2 | 17.1 | 14.9 | 16.5 |
| Logic (number correct, max = 6) | 1.6 | 1.3 | 1.7 | 1.5 | 3.0 | 3.9 | 1.7 |
| Theoretic explanations (max = 10) | 6.1 | 5.7 | 6.2 | 5.7 | 7.6 | 7.9 | 6.2 |
| Language objectivity (max = 3) | .7 | .5 | .9 | 1.2 | 1.3 | 1.3 | .7 |

**Source:** Adapted from Scribner and Cole (1981, p. 167).

were quite surprising. For most of the cognitive tasks, there were only scattered and small effects of literacy per se. Scribner and Cole (1981) concluded that unschooled literacy (such as acquisition of Vai script literacy in the home) does not produce the general cognitive effects previously reported by Luria (1976) and others.

Schooling, in contrast, did produce a number of effects. The most evident effect was that schooling, especially with English instruction, increased the ability to provide verbal explanations and justifications. The participants who had attended school were much better able to provide coherent explanations of their answers than those who hadn't attended school. The group differences in explanations were sometimes evident even when the schooled and unschooled groups did not differ in performance. In other words, schooling affected not so much which responses were chosen but rather the skill with which respondents could explain and justify their choices.

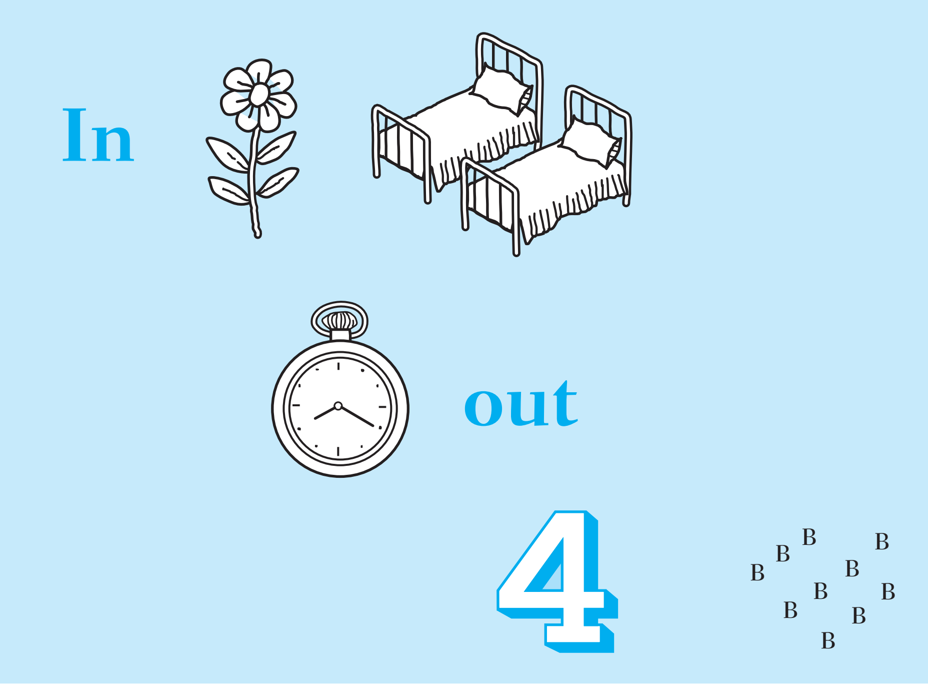
Scribner and Cole (1981) did discover literacy effects on some specific tasks, however. Most had to do with knowledge of language in one form or another. For example, literate participants were more likely to give good explanations of what makes for grammaticality of sentences in Vai. They also found it easier to learn to "read" other scripts, modeled after children's rebus puzzles (see Figure 16-10 for an example of a rebus puzzle). Scribner and Cole used these principles to invent Vai rebuses and taught these puzzles to both Vai-literate (unschooled) and nonliterate villagers. Literate villagers learned the task much more easily and significantly outperformed the nonliterate villagers.

What can we make of Scribner and Cole's (1981) findings? Contrary to some conventional wisdom, their studies do not support the idea that either literacy or schooling has profound effects on the ways in which cognitive processes operate. Although on some tasks, schooled and/or literate participants outperformed unschooled, nonliterate participants, the latter group often performed just as well, or only slightly worse, than the former groups. However, both literacy and schooling do apparently affect the ways in which some cognitive tasks are carried out, at least in some circumstances. So apparently both schooling and literacy make a difference to cognition, at least sometimes.

Reviewing all their findings, Scribner and Cole (1981) developed a "practice account of literacy" as a framework for understanding the experimental results. By *practice,* they refer to "a recurrent, goal-directed sequence of activities using a particular technology and particular systems of knowledge" (p. 236). These authors examined the knowledge and skills required for literacy and the knowledge and skills that the practice of literacy enables. What one does to become literate and what one does when one practices his or her literacy (say, by reading or writing a letter) strengthen some very specific skills. Scribner and Cole asserted that literacy does not promote broad, general cognitive changes but rather more localized and task-specific contextualized ones.

**FIGURE 16-10** ■ *Example of a rebus puzzle. Translation: In flower beds, watch out for bees.*

**SOURCE:** Adapted from Scribner and Cole (1981).



The same kind of argument might account for the effects of schooling. Recall that schooled Vai outperformed unschooled Vai only on tasks requiring verbal explanations. Scribner and Cole (1981) pointed to the "practice" of schooling, particularly English schooling, as a potent cause. Schools are places where a premium is placed on the ability to offer an articulate set of reasons for one's responses and to figure out ways to approach and master tasks removed from practical experience (Bruner, 1966). No wonder, then, that those with the most experience in this setting show the most ability to apply the specific skills this setting promotes in other circumstances.

To summarize, Scribner and Cole (1981) argued that cognitive skills are often context bound. From their perspective, it seems unlikely that there exist many broad cognitive abilities or skills such as "thinking" or "categorization" that can be affected or improved by one or a few manipulations. Instead, these authors would argue that cognition is situated, or intimately bound, to the conditions in which it naturally occurs. One's culture and one's everyday surroundings and tasks establish both boundaries and possibilities for the cognitive tasks that are practiced and therefore strengthened. Context and culture affect, and are affected by, cognition.

## SITUATED COGNITION IN EVERYDAY SETTINGS

**Situated cognition** is not simply a phenomenon that occurs in foreign, distant cultures (Wilson & Myers, 2000). Cultural contexts affect cognition right here at home, as seen in some studies conducted in the workplace. Sylvia Scribner's work before her death included field studies in the United States at an industrial milk-processing plant (a "dairy"), investigating on-the-job cognition, or what she called "working intelligence" (Scribner, 1984, p. 9). In particular, she drew a distinction between practical and theoretical thought (Scribner, 1986). The latter is the kind of thinking demanded in many school activities: thinking divorced from a meaningful context, carried out on a task of perhaps limited interest, performed for its own sake. Practical thought, by contrast, is more familiar and involves thinking "embedded in the larger purposive activities of daily life . . . [that] functions to achieve the goals of those activities" (p. 15). Examples include figuring out a supermarket "best buy" or diagnosing the cause of a machinery malfunction.

The site of Scribner's (1984) field studies employed 300 people in both white- and blue-collar positions. Certain blue-collar tasks were selected for study. These included product assembly (a warehouse job), inventory, and pricing delivery tickets. Scribner and associates began by observing people performing these jobs under normal working conditions, then constructed and presented workers with experimental simulations of these tasks.

From her earlier cross-cultural research, Scribner (1984) believed that cognitive skills are dependent on "socially organized experiences" (p. 10). In other words, the way in which a cognitive task is approached varies according to the environment and the context. She found the same sorts of patterns emerging in the dairy: Even a task as seemingly basic as mental calculation was accomplished in different ways by the same people in different circumstances.

The product assemblers (or preloaders, as they are sometimes called) provide a concrete example. Their job consists mainly of putting together specified quantities of various products and getting them ready to be loaded onto trucks. Scribner (1984) described the working conditions in more detail:

> Product assembly is a warehouse job. It is classified as unskilled manual labor and is one of the lowest paying jobs in the dairy. The perishable nature of dairy products requires that warehouse temperature be maintained at 38 degrees Fahrenheit; accordingly, the warehouse is, and is referred to as, an icebox.
>
> During the day, thousands of cases of milk products (e.g., skim milk, chocolate milk) and fruit drinks are moved on conveyor belts from the plant filling machines into the icebox, where they are stacked in designated areas along with many other dairy products (e.g., yogurt, cottage cheese). Preloaders arrive at the icebox at 6 P.M. Awaiting them is a sheaf of route delivery orders, called load-out

> order forms. Each form lists the products and their amounts that a wholesale driver has ordered for his next day's delivery. The preloader's task is to locate each product. Using a long metal "hook," he pulls the required number of cases and partial cases of that product and transports them to a common assembly area near a moving track that circles the icebox.
>
> When all the items of a given truck order are assembled, they are pulled onto the track and carried past a checkpoint to the loading platform. (pp. 18–19)

Scribner noticed an interesting problem that preloaders faced in their jobs. Truck drivers wrote orders that expressed quantities of items in terms of one set of units (for example, quarts of milk, half-pints of chocolate milk), but fluid products in the warehouse were stored in cases, not in units. Cases of all products were the same size but contained a different number of units, depending on the product. So a full case could contain 4 gallon units, 9 half-gallon units, 16 quart units, 32 pint units, or 48 half-pint units.

Load-out forms were created by computer by converting drivers' orders into cases. So a particular driver's request for 4 gallons of fruit juice would be translated into one case. Often a driver's request did not divide evenly into number of cases. For example, if a driver requested 5 gallons of milk, that would translate into one case plus one unit. The load-out forms followed the following convention: If the number of "leftover" units was equal to half a case or less, the order was expressed as the number of cases plus the number of units (as in the 5-gallon example). If the number of "leftover" units was more than half a case, the number was expressed as the number of cases minus the number of units. So in the case of quarts (which come 16 to a case), if a driver ordered 30 quarts of chocolate milk, the load-out form would read 2 (cases = 32 quarts) − 2 (quarts)—that is, 32 − 2 = 30. (Warning: This system is not intuitive, so work through this example carefully yourself.)

Scribner's question was how preloaders dealt with mixed numbers, such as 3 + 1, or 7 − 5, in assembling orders. You might think such a question would be easily answered in a fairly obvious way: A preloader with an order for 1 − 6 would simply grab one case and remove 6 units from it. But this is not what happened.

In fact, the preloaders handled the very same problem (that is, 1 − 6) in several different ways. Sometimes they filled the order in the "obvious" way just described. Other times, they mentally "rewrote" the order and used nearby partially filled cases to reduce the actual number of units that had to be moved. For example, when a nearby partially filled case of quarts (remember, 16 quarts to the case) contained 14 quarts, the preloader simply removed 4 (1 case − 6 quarts = 10 quarts; 14 quarts − 4 quarts = 10 quarts). In another situation, a partially filled case contained 8 quarts, and the preloader simply added 2 more.

Scribner (1984, 1986) found that although the same problem was solved in different ways, the solution always honored the following rule: Satisfy the order with the least number of moves—that is, the least number of transfers of product units. Even when the "saving" of labor was small (for example, saving one transfer in an order totaling 500 units), experienced preloaders rapidly and almost automatically calculated and followed the most efficient solution. The mental calculations required are impressive because of both the rapidity and the accuracy of calculation. Errors were rare. And most of the time, the workers were assembling a group of orders at the same time, thus most certainly increasing the cognitive demands.

It also turned out that on-the-job training was necessary to develop this cognitive flexibility. "Novice" preloaders—that is, other workers in the dairy and a comparison group of ninth-graders—were much less efficient and skilled, relative to the preloaders, at finding the optimal solution. Scribner (1984) constructed a simulation task with various orders and administered it to other dairy workers and to a group of ninth-grade students. When the optimal solution required some mental transformation of the order, preloaders found it about 72% of the time; inventory people (many of whom had some experience working as a preloader), 65%; clerks at the dairy (with little if any product assembly experience), 47%; and ninth-graders, 25%. Students in particular tended to be very "algorithmic" and "literal" in their approaches to problems, solving each problem in the same way and in the way specified on the load-out form even when much easier strategies (that required some mental transformations) were available.

Scribner (1986) found similar examples of cognitive flexibility in other experienced workers working at other jobs. She concluded that although formal problem solving—such as that required in school, on tests, and in many cognitive psychology experiments—requires or encourages set approaches and fixed rules, practical thinking does not. Instead, practical thinking "frequently hinges on an apt formulation or redefinition of the initial problem" (p. 21). Practical problem solving is flexible and requires different approaches to the "same" problem, with each approach tailored to the immediate context. Note the difference between this kind of thinking and "academic" thinking, typically requiring or at least encouraging all instances of a problem to be solved in the same way.

Similar findings were reported in another kind of "work" setting, a grocery store (Lave et al., 1984). Although not generally thought of as part of a paying job, grocery shopping is a frequent activity that must be completed to maintain a family. Lave and associates used the grocery store as a setting for studies of cognitive processing in everyday life. These authors studied 25 grocery shoppers. Participants represented a range of socioeconomic statuses and had varying educational backgrounds. Researchers accompanied shoppers throughout shopping trips and recorded conversations they had with shoppers.

Typical supermarkets contain around 7000 distinct items, and typical shoppers purchase about 50 weekly (Lave et al., 1984). Obviously, then, the number of potential decisions is quite large. How does the typical shopper manage to finish in about an hour? Again, the answer has to do with cognitive flexibility and adapting solutions to specific features of the problem.

One shopper, for example, found a package of cheese marked with a price that the shopper considered surprisingly high. To determine whether the price was correct, he found another package of cheese in the bin that weighed approximately the same amount. He then compared the prices on the two packages and indeed found them discrepant. Which one had the error? To find out, he compared these two packages to others in the bin, determining that the first one was, in fact, priced incorrectly. Notice here a "saving" in amount of mental effort: Although he could have calculated the price per ounce of each package, such calculations are mentally demanding and subject to error. Instead, he found an alternative way of solving the problem that was both more easily accomplished and less likely to be inaccurate.

Lave et al. (1984) were specifically interested in the arithmetic people used in grocery stores. They found that people's in-store arithmetic was virtually flawless—accuracy was 98%, compared with an average accuracy of 59% that the same people had on "school-like" arithmetic tests. Why the discrepancy? In

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*Lave and associates have used the grocery store as a setting for studies of cognitive processing in everyday life.*

part, people often invented ways of circumventing the traditional calculations, as in the example just given. Again, we see that the skills learned in school may be used outside the classroom but in ways that can be much more creative, flexible, and effective.

Ceci and Roazzi (1994) described similar findings reported by Carraher and associates with Brazilian children who worked as street vendors. When given problems embedded in real-life situations (for example, "If a large coconut costs 76 cruzeiros, and a small one costs 50, how much do the two cost together?"), children's performance averaged 98% correct. When posed as a formal test ("How much is 76 + 50?"), performance averaged only 37% correct.

Again, the point of much of the work described in this chapter is to show that much of what we take to be "the" way cognition works is really "a" way cognition works in a particular setting. Cognitive processes do not always work the same way, and some cognitive processes we may regard as fundamental (for example, processes involved in perception or memory or thinking) may change radically, even in adults. Nisbett and Norenzayan (2002) remind us that "Cultural practices and cognitive processes constitute one another. Cultural practices encourage and sustain certain kinds of cognitive processes, which then perpetuate the cultural practices" (p. 562).

## SUMMARY

1. Cross-cultural cognitive research has shown that the ways in which a cognitive task is approached and executed need not be exactly the same for all people at all times. Some tasks, because they are familiar, are easier, at least in the way expected by a cognitive psychologist from mainstream U.S. culture. As Wober (1969) put it, too often the blind adoption of cognitive tasks developed in one culture to study the cognition of people from another culture simply measures "How well can they do our tricks?" (p. 488). People from the second culture may perform poorly on the test but still have the cognitive capacities the test was designed to measure.
2. People from different cultures find ways of solving the cognitive (and other) challenges that confront them. A given environment, including a cultural one, strengthens certain skills, strategies, and approaches at the expense of others. This in turn makes certain tasks easier and more "natural" and others harder.
3. As noted earlier, cognition is often quite flexible. Practice with any task typically speeds execution and enables greater accuracy. This point raises another, however: Practice often affects the way a task is done. This suggests that researchers need to assess not only the familiarity of a task to a person from a given culture but also the person's specific level of practice with that (or a similar) task.
4. Formal schooling changes some, although certainly not all, important aspects of cognitive processing. In particular, schooling affects one's ability to deal with more

"abstract" materials; to rely less heavily on contextual, immediate cues from the surrounding environment; and to explain one's responses and thinking more clearly. Schooling also helps people figure out how to approach novel tasks, especially in planning and structuring. All in all, schooling apparently helps people "step back" from their everyday routine and also promotes their thinking from different points of view. And, as the Laboratory of Comparative Human Cognition (1983) pointed out, school prepares people especially well to participate in cognitive psychology experiments!

5. Interestingly, basic academic skills turn out not to be entirely optimal in the cognitive challenges that confront people in their everyday lives. Practice with a specific task, whether grocery shopping or conducting inventory, apparently leads to the invention of clever shortcuts that reduce the effort (mental or physical) required and increase accuracy. Although schools may insist that students approach all calculation problems in similar ways, research is beginning to suggest that in the "real world," the approaches taken to a problem vary with the immediate context.
6. A general and important point is that models of a cognitive process often presume, implicitly, that the task in question is universally important and familiar, an assumption that researchers have recently questioned. Similarly, existing cognitive models often assume that the same cognitive procedures are used the same way for all versions of a problem, although new research challenges this belief. Dropping these assumptions will no doubt make the job of cognitive researchers much more difficult. In the long run, however, the new models will be more accurate and more complete.

## REVIEW QUESTIONS

1. What does it mean to assert that a particular cognitive capacity or skill is culturally relative or culturally universal? How do the assertions differ?
2. Describe Hudson's studies of pictorial perception, and discuss their implications.
3. Kearins concluded that culture can impose "environmental pressure" on certain cognitive skills. Discuss this conclusion with respect to empirical findings (those of either Kearins or others).
4. Schooling appears to help cognitive performance, especially on tasks such as formal reasoning. Explain why this might be so.
5. Schooling and literacy are distinct factors that appear to affect cognitive performance differently. Describe one or two of the differences, and speculate on reasons for the difference.
6. How are Scribner's studies of dairy workers consistent with, and inconsistent with, cross-cultural studies of cognition?

## KEY TERMS

cultural relativism
cultural universality
culture
literacy
schooling
situated cognition

## CogLab DEMONSTRATIONS

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

The **Müller-Lyer illusion,** discussed in this chapter, is illustrated in the CogLab demonstration of the same name.

## WEB RESOURCES

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

# Glossary

**ablation** Removal of cells or tissues, often through surgical means.

**adaptive control of thought (ACT) model of memory** A theory of memory developed by John Anderson that specifies a networked memory comprised of working memory, declarative memory, and procedural memory.

**affordance** A perceptual property of objects, places, and events that makes clear what actions or behaviors on the part of the perceiver are permitted in interaction with the object, place, or event.

**amygdala** An area of brain tissue with extensive connections to the olfactory system and hypothalamus, thought to be involved in mood, feeling, instinct, and short-term memory.

**analogical reasoning** Drawing inductive inferences that specify a fourth (D) term that projects a relationship found between the first two (A and B) terms onto the third (C) term of the analogy, in problems of the form A is to B and C is to D.

**analytic processing** A mode of processing information in which attention is paid to specific dimensions, features, or parts of the stimuli rather than to the overall or global aspects.

**anchoring** A decision-making heuristic in which final estimates are heavily influenced by initial value estimates.

**anterograde amnesia** Lack of memory for events that occur after a brain injury.

**aphasia** A disorder of language, thought to have neurological causes, in which either language production, language reception, or both are disrupted.

**artifact** Concept pertaining to manufactured or human-designed objects.

**artificial intelligence** A branch of computer science concerned with creating computers that mimic human performance on cognitive tasks.

**association** A connection or link between two units or elements.

**attention** Cognitive resources, mental effort, or concentration devoted to a cognitive process.

**attention hypothesis of automatization** The proposal that attention is needed during a learning phase of a new task.

**attentional capture** A phenomenon in which certain stimuli seem to "pop out" and require a person to shift cognitive resources to them, automatically.

**attenuation theory** A model of attention in which unattended perceptual events are transmitted in weakened form but not blocked completely before being processed for meaning.

**autobiographical memory** Memory for events and other information from one's own life.

**automatic processing** The carrying out of a cognitive task with minimal resources. Typically, automatic processing occurs without intention, interferes minimally with other cognitive tasks, and may not involve conscious awareness.

**availability heuristic** A strategy in which one estimates the frequency or probability of an event by the ease with which mental operations, such as retrieval of examples or construction of examples, can be carried out.

**backtracking** A problem-solving technique that involves keeping track of where in the solving process assumptions are made, so they may later be changed.

**basic level of categories** A hypothesized type of concept thought to be at a psychologically fundamental level of abstraction.

**behaviorism** A school of psychology that seeks to define psychological research in terms of observable measures, emphasizing the scientific study of behavior.

**believability effect** The tendency to draw or accept conclusions from premises when the content of the conclusion makes intuitive sense, regardless of the logical necessity.

**between-subjects design** A research paradigm in which different experimental subjects participate in different experimental conditions.

**bias** A tendency to think in a certain way or to follow certain procedures regardless of the facts of the matter.

**bottom-up process** Cognitive (usually perceptual) process guided by environmental input. Also called "data-driven" process.

**brain imaging** The construction of pictures of the anatomy and functioning of intact brains through such techniques as computerized axial tomography (CAT, or CT), positron emission tomography (PET), magnetic resonance imaging (MRI), or functional magnetic resonance imaging (fMRI).

**Broca's aphasia** Also called *expressive* or *motor aphasia;* symptoms of this organic disorder include difficulty in speaking, using grammar, and finding appropriate words.

**calibration curve** A plot of accuracy against confidence judgments. The more the curve approaches a 45-degree line, the better the "calibration" or "fit" between the two.

**capacity** The sum total of cognitive resources available at any given time.

**CAT scan** *See* **computerized axial tomography scan.**

**categorization** The organization of information into coherent, meaningful groups.

**category** A grouping of items sharing one or more similarities.

**central executive** The proposed component of working memory responsible for directing the flow of information and selecting what information to work with.

**cerebellum** Part of the brain that controls balance and muscular coordination.

**cerebral cortex** The surface of the cerebrum, the largest structure of the brain, containing both sensory and motor nerve cell bodies.

**change blindness** The inability to detect changes to an object or scene, especially when given different views of that object or scene.

**characteristic feature** A feature that is typically, though not always, a part of an object or concept.

**chunking** The formation of individual units of information into larger units. This is often used as a means of overcoming short-term memory limitations.

**classical view of concepts** The idea that all examples or instances of a concept share fundamental characteristics or features.

**clinical interview** A research paradigm in which an investigator begins by asking participants a series of open-ended questions but follows up on the responses with specific questions that have been prepared in advance.

**coding** The form in which information is mentally or internally represented.

**cognitive economy** A principle of hierarchical semantic networks such that properties and facts about a node are stored at the highest level possible. For example, the fact "is alive" would be stored with the node for "animal" rather than stored with each node under animal, such as "dog," "cat," and the like.

**cognitive illusions** The systematic biases and errors in human decision making.

**cognitive neuropsychology** A school of psychology that investigates the cognitive abilities and deficits of people with damaged or otherwise unusual brain structures.

**cognitive overload** Breakdown of cognitive processing that occurs when the available information exceeds processing capacity.

**cognitive revolution** A movement in psychology that culminated after World War II, characterized by a belief in the empirical accessibility of mental states and events.

**cognitive science** An interdisciplinary field drawing on research from cognitive psychology, computer science, philosophy, linguistics, neuroscience, and anthropology. The central issues addressed involve the nature of mind and cognition and how information is acquired, stored, and represented.

**cognitive style** A habitual and/or preferred means of approaching cognitive tasks.

**cognitive tempo** A cognitive style dimension along which people differ in terms of their ability to respond slowly and carefully as opposed to quickly and with errors.

**componential approach to the study of reasoning** An approach to cognitive psychology in which performance on a task is analyzed into its component cognitive processes.

**computer metaphor** The basis for the information-processing view of the brain. Different types of psychological processes are thought to be analogous to the workings of a computer processor.

**computerized axial tomography (CAT, or CT) scan** An imaging technique in which a highly focused beam of X-rays is passed through the body from many different angles. Differing density of the organs of the body result in different deflections of the X-rays, which allows visualization of the organ.

**concept** A mental representation of a category.

**confirmation bias** A tendency to seek only information consistent with one's hypothesis.

**connectionism** An approach to cognition emphasizing parallel processing of information through immense networks of interconnected nodes. Models developed in the connectionist tradition are sometimes declared to share certain similarities with the way collections of neurons operate in the brain; hence, some connectionist models are referred to as *neural networks.*

**constructivist approach to perception** An understanding of perception as a process requiring the active construction of subjective mental representations not only from perceptual information, but from long-term memory as well.

**content effect** Performance variability on reasoning tasks that require identical kinds of formal reasoning but are dissimilar in superficial content.

**context effect** The effect on a cognitive process (for example, perception) of the information surrounding the target object or event. Sometimes called "expectation effect" because the context is thought to set up certain expectations in the mind of the cognitive processor.

**contradiction** A statement that is false by definition of its form (for example, "A and not-A are both true").

**controlled observation** A research paradigm in which an observer standardizes the conditions of observation for all participants, often introducing specific manipulations and recording responses.

**controlled processing** The carrying out of a cognitive task with a deliberate allocation of cognitive resources. Typically, controlled processing occurs on difficult and/or unfamiliar tasks requiring attention and is under conscious control.

**corpus callosum** The large neural structure containing fibers that connect the right and left cerebral hemispheres.

**creativity** Cognitive processes that employ appropriate novelty; originality that suits some purpose.

**critical thinking** A type of thinking that involves careful examination of assumptions and evidence and that is purposeful and deliberate.

**cue overload** A principle of memory that states a retrieval cue will be most effective when it is highly distinctive and not related to any other target memories.

**cultural relativism** A belief that cognitive practices, beliefs, competences, and capacities differ from culture to culture, depending on the tasks and contexts specific to a culture.

**cultural universality** A belief that cognitive practices, beliefs, competences, and capacities do not differ from culture to culture but are common to humankind.

**culture** The attitudes, traditions, artifacts, and behaviors that characterize a group of people.

**data-driven processes** *See* **bottom-up processes.**

**decay** A hypothesized process of forgetting in which material is thought to erode, break apart, or otherwise disintegrate or fade.

**decision analysis** A technology that helps people gather and integrate information in an optimal way.

**decision making** The process(es) by which an individual selects one course of action from among alternatives.

**decision structuring** The process(es) by which an individual establishes the criteria and options for consideration.

**declarative memory** A memory system thought to contain knowledge, facts, information, ideas, or anything that can be recalled and described in words, pictures, or symbols.

**deductive reasoning** Drawing conclusions from only the given premises.

**deductive validity** A property of some logical arguments such that it is impossible for the premises to be true and the conclusion(s) to be false.

**defining feature** A feature that is necessarily a part of an object or concept. Also called a *necessary feature.*

**demand characteristic** A property of certain tasks such that an experimental subject's behavior or responses are "cued" by the task itself.

**descriptive models of thinking** Models that depict the processes people actually use in making decisions or solving problems.

**dichotic listening task** A task in which a person hears two or more different, specially recorded messages over earphones and is asked to attend to one of them.

**direct perception** A theory of perception, proposed by James J. Gibson, holding that information in the world is "picked up on" by the cognitive processor without much construction of internal representations or inferences. The emphasis is on direct acquisition of information.

**distal stimulus** An object, event, or pattern as it exists in the world. Contrast with **proximal stimulus.**

**divided attention** The ways in which a cognitive processor allocates cognitive resources to two or more tasks that are carried out simultaneously.

**dual-coding hypothesis** Paivio's assertion that long-term memory can code information in two distinct ways, verbally and visually, and that items coded both ways (for example, pictures or concrete words) are more easily recalled than items coded in only one way (for example, abstract words).

**dual-task performance** An experimental paradigm involving presentation of two tasks for a person to work on simultaneously.

**echo** A sensory memory for auditory stimuli.

**ecological approach** An approach to the study of cognition emphasizing the natural contexts or settings in which cognitive activities occur, and the influences such settings have in the ways in which cognitive activities are acquired, practiced, and executed.

**ecological validity** A property of research such that the focus of study is something that occurs naturally outside an experimental laboratory.

**EEG** *See* **electroencephalography.**

**effect size (*d*)** A measure used in meta-analysis, defined as the difference in mean scores between two groups, divided by the average standard deviation for the two groups.

**electroencephalography (EEG)** A technique to measure brain activity, specifically, to detect different states of consciousness. Metal electrodes are positioned all over the scalp. The waveforms that are recorded change in predictable ways when the person being recorded is awake and alert, drowsy, asleep, or in a coma.

**elimination-by-aspects strategy** In decision making, the elimination of alternatives that exceed a threshold value on one or more dimensions.

**empiricism** A philosophical doctrine emphasizing the role of experience in the acquisition of knowledge.

**encoding** The cognitive process(es) by which information is translated into a mental or internal representation and stored.

**encoding specificity** A principle of retrieval asserted by Tulving: At the time material is first put into long-term memory, it is encoded in a particular way, depending on the context present at the time; at the time of recall, the person is at a great advantage if the same information available at encoding is once again available.

**encoding variability** The way the encoding of information varies as a function of context.

**episodic memory** A memory system proposed by Tulving that is thought to hold memories of specific events with which the cognitive processor had direct experience.

**ERP** *See* **event-related potential.**

**event-related potential (ERP)** An electrical recording technique to measure the response of the brain to various stimulus events.

**everyday reasoning** Mundane reasoning that differs from formal reasoning in its use of implicit premises, multiple solutions, personal relevance, and possible emotional involvement.

**executive functioning** Cognitive processes including planning, making decisions, implementing strategies, inhibiting inappropriate behaviors, and using working memory to process information.

**exemplar view of concepts** The idea that a concept consists of mental representations of actual instances or examples.

**exhaustive search** A search for information in which each item in a set is examined, even after the target is found.

**expected utility theory** A normative model of decision making in which the decision maker weights the personal importance and the probabilities of different outcomes in choosing among alternatives in order to maximize overall satisfaction of personal goals.

**experiment** A test of a scientific theory in which the researcher manipulates the independent variable.

**experimental control** A property of research such that the causes of different behaviors or other phenomenon can be isolated and tested. Typically, this involves manipulating independent variables and holding constant all factors but the one(s) of interest.

**experimenter expectancy effect** The influence on the performance of experimental participants generated by an experimenter's beliefs or hypotheses, which somehow get subtly transmitted to the participants.

**expert/novice differences** A dimension of individual differences in which people's analytic approach in perception or problem solving increases as they gain familiarity with a domain.

**expert system** A computer program designed to model the judgments of a human expert in a particular field.

**explicit memory** Consciously recalled or recollected memory.

**expressive aphasia** *See* **Broca's aphasia.**

**eyewitness memory** A narrative memory of a personally witnessed event.

**faculty psychology** The theory that different mental abilities, such as reading or computation, are independent and autonomous functions, carried out in different parts of the brain.

**fallacy** An erroneous argument.

**false memory** "Recollections" of "events" that never in fact occurred. See also **recovered memory.**

**family resemblance** A structure of categories in which each member shares different features with different members. Few, if any, features are shared by every single member of the category.

**fan effect** The phenomenon whereby retrieval time to retrieve a particular fact about a concept increases as more facts are known about that concept.

**featural analysis** A model of perception emphasizing the analysis of a stimulus into parts, called *features.*

**feature** A component, or part, of an object, event, or representation.

**feature comparison model of semantic memory** A model of semantic memory positing that words or concepts are mentally represented in terms of a set of elements called *features.*

**feature integration theory** A proposal that perception of familiar stimuli occurs in two stages. The first, automatic, stage involves the perception of object features. The second, attentional, stage involves the integration and unification of those features.

**field dependence/field independence (FD/FI)** A cognitive style dimension referring to the relative difficulty or ease individuals have in ignoring background context to identify parts of a figure as separate from a whole.

**filter theory** A theory of attention proposing that information that exceeds the capacity of a processor to process at any given time is blocked from further processing.

**flashbulb memory** A phenomenon in which people recall their personal circumstances (for example, where they were, whom they were with, what they were doing) at the time they heard of or witnessed an unexpected and very significant event (for example, an assassination, a natural disaster).

**fMRI** *See* **functional magnetic resonance imaging.**

**forebrain** The part of the brain containing the thalamus, hypothalamus, hippocampus, amygdala, and the cerebral cortex.

**forgetting** The processes that prevent information from being retrieved from a memory store.

**form perception** The process by which the brain differentiates objects from their backgrounds.

**formal reasoning** Reasoning about problems with explicit premises, finite solutions, and well-defined operations.

**framing effect** Decision-making bias caused by a propensity to evaluate outcomes as positive or negative changes from their current state.

**frontal lobe** A division of the cerebral cortex located just beneath the forehead containing the motor cortex, premotor cortex, and the prefrontal cortex.

**functional fixedness** A problem-solving phenomenon in which people have difficulty seeing alternate uses for common objects.

**functional magnetic resonance imaging (fMRI)** An imaging technique that uses MRI equipment to examine blood flow in a noninvasive, nonradioactive manner.

**functionalism** A school of psychology emphasizing questions such as why the mind or a particular cognitive process works the way(s) it does.

**gambler's fallacy** An erroneous belief that a random process (for example, a coin flip or a spin of a roulette wheel) will automatically keep track of the outcomes in order to make the overall rate of an outcome in the short run equal to the overall rate of that outcome in the long run.

**generate-and-test technique** A problem-solving strategy in which the solver enumerates (generates) possible solutions and then tries each to see if it constitutes a solution.

**genetic epistemology** A Piagetian approach to the study of cognitive development that emphasizes the intellectual structures underlying cognitive experience at different developmental points and the ways in which the structures adapt to environmental experience.

**geon** A simple geometric component hypothesized to be used in the recognition of objects.

**Gestalt principles of perceptual organization** Laws that explain the regularities in the way people come to the perceptual interpretations of stimuli. The emphasis is on the apprehension of whole structures rather on than the detection and assembly of parts of structures.

**Gestalt psychology** A school of psychology emphasizing the study of whole entities rather than simple elements. Gestalt psychologists concentrate on problems of perception and problem solving and argue that people's cognitive experience is not reducible to their experience of simple elements (for example, sensations) but, rather, to the overall structure(s) of their experience.

**GPS (General Problem Solver)** A computer program developed by Allan Newell and Herbert Simon, that solved problems in crypt arithmetic and logic using means–ends analysis.

**grammar** A system of rules that produces well-formed, or "legal," entities, such as sentences of a language.

**Gricean maxims of cooperative conversation** Pragmatic rules of conversation, including moderation of quantity, quality, relevance, and clarity.

**heuristic** A rule of thumb, or shortcut method, used in thinking, reasoning, and/or decision making.

**hierarchical semantic network model of semantic memory** A model of semantic memory organized in terms of nodes and links, which stores properties at the highest relevant node to conserve cognitive economy.

**hindbrain** The part of the brain, containing some of the most evolutionarily primitive structures, that is responsible for transmitting information from the spinal cord to the brain, regulating life support functions, and helping to maintain balance.

**hindsight bias** A tendency to exaggerate the certainty of what could have been anticipated ahead of time.

**hippocampus** A structure of the brain in the medial temporal lobe; damage or removal can result in amnesia.

**holistic processing of information** Attending to global aspects of a situation in processing information about it.

**human factors engineering** An applied area of research that focuses on the design of equipment and technology that are well suited to people's cognitive capabilities.

**hypothalamus** A structure in the forebrain that controls the pituitary gland and so-called homeostatic behaviors, such as eating, drinking, temperature control, sleeping, sexual behaviors, and emotional reactions.

**hypothesis testing** An inductive reasoning strategy that involves testing a number of possible solutions to a problem and modifying them based on feedback.

**icon** A sensory memory for visual stimuli.

**ill-defined problem** A problem that does not have the goals, starting information, and/or legal steps stated explicitly.

**illusory correlation** An association between factors that is not supported by data but seems plausible.

**image theory** A descriptive theory of decision making that posits that the process consists of two stages: (1) a noncompensatory screening of options against the decision maker's image of values and future, in which the number of options is reduced to a very small set, and (2) if necessary, a compensatory choice process.

**imaginal scanning** A task in which a participant is asked to form a mental image and to scan over it from one point to another.

**implicit encoding** A principle of imagery that holds mental imagery is used in retrieving information about physical properties of objects, or of physical relationships among objects, that may not have been explicitly encoded.

**implicit learning** Learning that occurs without explicit awareness of what has been learned.

**implicit memory** Memory that is not deliberate or conscious but exhibits evidence of prior experience.

**inattentional blindness** The phenomenon of not perceiving a stimulus that might be literally right in front of you, unless you are paying attention to it.

**incidental learning** The retention of information even when it is not required of, or even intended by, the processor.

**incubation** Unconscious processing that works on a specific problem while the mind is otherwise occupied.

**individual differences** Stable patterns of performance that differ qualitatively and/or quantitatively across individuals.

**inductive reasoning** Reasoning that involves drawing conclusions that are suggested, but not necessarily true.

**inductive strength** A property of some logical arguments such that it is improbable (but not impossible) for the premises to be true and the conclusion false.

**inference rule** Hypothesized special-purpose rule used in reasoning to draw conclusions.

**information processing approach** An approach to cognition that uses a computer metaphor in its explanations. Information processing equates cognition with the acquisition, storage, and manipulation of information (for example, what we see, hear, read about, think about) through a system consisting of various storage places and systems of exchange.

**informational encapsulation** A property of a cognitive process whereby it functions without drawing on information from other cognitive processes.

**informationally encapsulated process** A process with the property of informational encapsulation.

**intelligence** Postulated by some psychologists to represent the sum total of a person's cognitive abilities and resources.

**interference** A hypothesized process of forgetting in which material is thought to be buried or otherwise displaced by other information but still exists somewhere in a memory store.

**introspection** A methodological technique in which trained observers are asked to reflect on, and report on, their conscious experience while performing cognitive tasks.

**knowledge representation** The mental depiction, storage, and organization of information.

**knowledge-based view of concepts** The idea that concepts function in relation to their instances as a scientific theory does to data supporting it.

**language** A system of communication that is governed by a system of rules (a grammar) and can express an infinite number of propositions.

**language acquisition** The process(es) by which a cognitive processor comes to develop linguistic competence and performance.

**lateralization** Specialization of function of the two cerebral hemispheres.

**late-selection theory** A model of attention in which all perceptual messages, whether attended or not, are processed for some meaning.

**levels-of-processing theory of memory** An alternative to the modal view of memory, proposed by Craik and Lockhart, that postulates that memory depends not on a particular memory store but on the initial processing done to the information at the time of acquisition. "Shallow" or superficial levels of processing (for example, processing at the level of visual shape or acoustic sound) are thought to lead to less retention than "deeper" levels of processing (for example, processing done on the meaning of the information).

**lexical ambiguity** The idea that some words have different meanings; for example, *bank* can refer to the side of a river or to a financial institution.

**lexical decision task** A task in which an experimental subject is presented with letter strings and asked to judge, as quickly as possible, if the strings form words.

**lexicon** A mental store thought to hold a cognitive processor's knowledge of words, including their spelling, pronunciation, definition, part of speech, and so on.

**limited-capacity processor** A system that acquires, stores, manipulates, and/or transmits information but has fixed limits on the amount or rate of processing that it can accomplish.

**linguistic competence** Underlying knowledge that allows a cognitive processor to engage in a particular cognitive activity involving language, independent of behavior expressing that knowledge. Contrast with **linguistic performance.**

**linguistic performance** The behavior or responses actually produced by a cognitive processor engaged in a particular cognitive activity involving language. Contrast with **linguistic competence.**

**linguistics** A field of study focusing on the structure, use, and acquisition of language.

**literacy** The ability to read and write.

**localization of function** The "mapping" of brain areas to different cognitive or motor functions; identifying which neural regions control or are active when different activities take place.

**logical connectives** Symbols used in logic arguments to form compound propositions. Examples: &, ∨.

**long-term memory (LTM)** A memory store thought to have a large, possibly infinite capacity that holds onto incoming information for long periods of time, perhaps permanently. Also called *secondary memory.*

**long-term potentiation** A process, hypothesized to be a mechanism for long-term learning, in which neural circuits in the hippocampus are subjected to repeated and intense electrical stimulation, resulting in hippocampal cells that are more sensitive to stimuli than they were previously.

**LTM** *See* **long-term memory.**

**magnetic resonance imaging (MRI)** A body-imaging technique in which a person is surrounded with a strong magnetic field. Radio waves are directed at a particular part of the body, causing the centers of hydrogen atoms in those structures to align themselves in predictable ways. Computers collate information about how the atoms are aligning and produce a composite three-dimensional image.

**means–ends analysis** A problem-solving strategy in which the solver compares the goal to the current state, then chooses a step to reduce maximally the difference between them.

**medulla oblongata** A structure in the hindbrain that transmits information from the spinal cord to the brain and regulates life support functions such as respiration, blood pressure, coughing, sneezing, vomiting, and heart rate.

**memory** The cognitive processes underlying the storage, retention, and retrieval of information.

**memory consolidation** The biochemical process(es) by which neural synaptic connections are strengthened or weakened.

**memory system** A kind of memory (for example, episodic memory, semantic memory) that operates on distinct principles and stores a distinct kind of information.

**memory trace** The mental representation of stored information.

**mental models approach to the study of reasoning** The idea that reasoning proceeds with general-purpose cognitive processes used in the construction of mental representations.

**mental representation** An internal depiction of information.

**mental rotation** A type of visual imagery task in which subjects are asked to form an image of a stimulus and then to imagine how it would look as it rotates around a horizontal or vertical axis.

**mental set** The tendency to adopt a certain framework, strategy, or procedure based on immediate experience or context.

**meta-analysis** A technique to review findings in the literature involving the use of specific statistical methods in integrating the findings from different empirical studies.

**metacognition** Awareness or knowledge of one's own cognitive processes and systems.

**method of loci** A memorization method that requires the learner to visualize an ordered series of physical locations as mnemonic cues for a list of information.

**midbrain** The part of the brain containing structures that are involved in relaying information between other brain regions, or in regulating levels of alertness.

**mnemonics** Strategies to facilitate retention and later retrieval of information.

**modal model of memory** A theoretical approach to the study of memory that emphasizes the existence of different memory stores (for example, sensory memory, short-term memory, long-term memory).

**modularity hypothesis** Fodor's proposal that some cognitive processes, in particular language and perception, operate on only certain kinds of inputs and operate independent of the beliefs and other information available to the cognitive processor or other cognitive processes.

**mood-dependent memory effect** The empirical finding that people's ability to recall information is best when their mood at the time of recall matches their mood at the time of learning.

**morpheme** The smallest meaningful unit of language.

**motor cortex** A structure in the frontal lobe that controls fine motor movement in the body.

**MRI** *See* **magnetic resonance imaging.**

**multiattribute utility theory (MAUT)** A normative model of decision making that provides a means of integrating different dimensions and goals of a complex decision. It involves six steps: (a) breaking a decision down into independent dimensions, (b) determining the relative weights of each of those dimensions, (c) listing all the alternatives, (d) ranking all the alternatives along the dimensions, (e) multiplying the rankings by the weightings to determine a final value for each alternative, and (f) choosing the alternative with the highest value.

**multiple intelligences (MI) theory** Howard Gardner's theory that intelligence can be divided into distinct types, including musical, bodily-kinesthetic, logical-mathematical, linguistic, spatial, interpersonal, and intrapersonal intelligences.

**nativism** A philosophical doctrine emphasizing the role of innate factors in the acquisition of knowledge.

**naturalistic observation** A research paradigm in which an observer observes participants in familiar, everyday contexts while ideally remaining as unobtrusive as possible.

**natural-kind concept** Concepts pertaining to naturally occurring substances.

**need for cognition** A dimension of individual differences in which people differ in their motivation to take on intellectual challenges or tasks.

**neural network** *See* **connectionism.**

**nominal-kind concept** Concepts pertaining to ideas or objects that have well-delimited definitions.

**nonanalytic concept formation** Cognitive processes that implicitly acquire knowledge of a complex structure during the memorization of examples.

**normative models of thinking** Models that define ideal performance under ideal circumstances in making decisions or solving problems.

**occipital lobe** A division of the cerebral cortex located at the back of the head that is involved in the processing of visual information.

**overconfidence** An overly positive judgment of one's own decision-making abilities and performance.

**paired associates learning** A memory task in which experimental subjects are first presented with a list of pairs of words (for example, *flag–spoon*) and later asked to recall the second word in a pair (for example, *spoon*) when presented with the first (for example, *flag*).

**Pandemonium model** A model of letter perception based on a bottom-up hierarchy of feature detectors.

**paradigm** A body of knowledge that selects and highlights certain issues for study. It includes assumptions about how a particular phenomenon ought to be studied and the kinds of experimental methods and measures that are appropriate to use.

**parallel search** A search for information in which several stores or slots of information are simultaneously examined to match to the target.

**parietal lobe** A division of the cerebral cortex located at the top rear part of the head; contains the primary somatosensory cortex.

**pattern recognition** The classification of a stimulus into a category.

**percept** The outcome of a perceptual process; the meaningful interpretation of incoming information.

**perception** The interpretation of sensory information to yield a meaningful description or understanding.

**perceptual learning** The changes in perception that occur as a function of practice or experience with the stimuli.

**perceptual set** The tendency to perceive an object or pattern in a certain way, based on one's immediate perceptual experience.

**person–machine system** The idea that machinery operated by a person must be designed to interact with the operator's physical, cognitive, and motivational capacities and limitations.

**PET scan** *See* **positron emission tomography.**

**phoneme** The smallest unit of sound that makes a meaningful difference in a given language.

**phonetics** The study of speech sounds.

**phonological loop** The proposed component of working memory responsible for subvocally rehearsing auditory information.

**phonology** The study of the ways in which speech sounds are combined and altered in language.

**phrenology** The idea (now discredited) that psychological strengths and weaknesses could be precisely correlated to the relative sizes of different brain areas.

**plasticity** The ability of some brain regions to "take over" functions of damaged regions.

**pons** A structure in the hindbrain that acts as a neural relay center, facilitating the "crossover" of information between the left side of the body and the right side of the brain and vice versa. It is also involved in balance and in the processing of both visual and auditory information.

**positron emission tomography (PET)** A brain-imaging technique that shows which areas of the brain are most active at a given point in time.

**pragmatics** The rules governing the social aspects of language.

**prefrontal cortex** A region in the frontal lobe that is involved with executive functioning.

**premise** A statement, from which others are inferred, that helps establish what is already known about a problem.

**prescriptive models of thinking** Models that tell us how we "ought" to make decisions or solve problems but that take into account actual circumstances.

**primacy effect** The improvement in retention of information learned at the beginning of a task.

**primary somatosensory cortex** A region in the parietal lobe involved in the processing of sensory information from the body—for example, sensations of pain, pressure, touch, or temperature.

**priming** The facilitation in responding to one stimulus as a function of prior exposure to another stimulus.

**proactive interference** A phenomenon in which earlier learned material disrupts the learning of subsequent material.

**probability** Measurement of a degree of uncertainty, expressed as a number between 0 and 1.

**problem solving** The cognitive process(es) used in transforming starting information into a goal state, using specified means of solution.

**problem space hypothesis** The idea that problem solving is isomorphic to a search through a mental graph, with nodes corresponding to every possible state of affairs of a problem and connections corresponding to legal moves.

**procedural memory** A memory system thought to contain information concerning action and sequences of actions—for example, one's knowledge of how to ride a bicycle or swing a golf club.

**process dissociation framework** The idea that memory tasks typically call on a mixture of automatic and intentional cognitive processes.

**production rules** A hypothesized mental representation of procedural memory, which specifies a goal to be achieved, one or more conditions that must be true in order for the rule to be applied, and one or more actions that result from the application of the rule.

**propositional reasoning** Drawing conclusions from premises that are in the form of true or false assertions.

**propositional complexity of a sentence** The number of underlying distinct ideas in a sentence.

**prosopagnosia** A specific inability to recognize faces, even very familiar ones, with intact recognition of other objects.

**prototype** An abstract representation of an idealized member of a class of objects or events.

**prototype view of concepts** The idea that all concepts are organized around idealized mental representations of examples.

**proximal stimulus** Reception of information and its registration by a sense organ—for example, retinal images in the case of vision.

**psychological essentialism** The idea that people possess implicit theories about fundamental characteristics that all instances of a concept contain or embody.

**psychological refractory period (PRP)** An interval of time following presentation of a first stimulus during which a person cannot respond to a second stimulus, presumably because of a central bottleneck in attentional processing.

**quasi-experiment** An empirical study that appears to involve some, but incomplete, experimental control—for example, through nonrandom assignment of subjects to conditions.

**rationality** A property of thinking or decision making such that the processes used are selected with the processor's overall goals and principles in mind.

**reasoning** Cognitive process(es) used in transforming given information, called *premises,* into conclusions. Reasoning is often seen as a special kind of thinking.

**reasoning by analogy** Problem solving that employs an analogy between the current problem and another problem that has already been solved.

**recall** The retrieval of information in which the processor must generate most of the information without aids. *See also* **recognition.**

**recency effect** The improvement in retention of information learned at the end of a task.

**receptive aphasia** *See* **Wernicke's aphasia.**

**recognition** The retrieval of information in which the processor must decide whether the information presented has been previously presented. *See also* **recall.**

**recognition-primed decision making** A theory of expert decision making that holds that decision makers choose options based on analogy of a given situation with previously encountered situations.

**recovered memory** Autobiographical memories, usually of traumatic events, that are not accessible for some period of time but later become able to be retrieved. *See also* **false memory.**

**reflectivity/impulsivity** A cognitive style dimension referring to the way individuals trade off speed and accuracy of responding.

**rehearsal** A mnemonic strategy of repeating information (either aloud or silently) to facilitate retention and later retrieval.

**relational-organizational hypothesis** The idea that visual imagery aids memory by producing a greater number of associations.

**repetition priming** Priming that facilitates the cognitive processing of information after a recent exposure to that same information.

**representativeness heuristic** A belief that outcomes will always reflect characteristics of the process that generated them—for example, an expectation that the outcome of a series of coin flips will always look random.

**repressed memory** A controversial explanation of amnesia for traumatic events. *See also* **false memory, recovered memory.**

**retention duration** The amount of time a memory trace remains available for retrieval.

**retina** A layer of visual receptor cells at the rear of the eyeball.

**retinal image** A proximal stimulus for vision, consisting of the projection of light waves reflected from stimuli and projected to a surface at the back of the eye.

**retrieval** The processes by which stored information is brought back to conscious awareness.

**retrieval cue** A stimulus that helps a person recall or recognize stored information.

**retroactive interference** A phenomenon in which subsequently learned material lowers the probability of recalling earlier learned material.

**retrograde amnesia** Amnesia concerning old events.

**rules/heuristics approach to the study of reasoning** The idea that reasoning proceeds through the application of rules or heuristics, either general or domain specific.

**schema** An organized framework for representing knowledge that typically includes characters, plots, and settings, and incorporates both general knowledge about the world and information about particular events.

**schema theory** A theory of attention that claims unattended information is never perceived.

**schemata** Frameworks for organizing and representing knowledge that contain roles, variables, and fixed parts.

**schemata/scripts view of concepts** The idea that all concepts are schemata.

**schooling** The amount of time an individual spends in a formal academic setting.

**script** A schema for routine events.

**selective attention** The focusing of cognitive resources on one or a small number of tasks to the exclusion of others.

**self-terminating search** A search for information that stops when a target is found.

**semantic memory** A memory system proposed by Tulving that is thought to hold memories of general knowledge.

**semantic network** A depiction of semantic memory consisting of nodes (which roughly correspond to words or concepts) and connections between nodes.

**semantic priming** A phenomenon in which exposure to one word (e.g., *nurse*) facilitates the recognition of semantically related words (e.g., *doctor*).

**semantics** The study of meaning.

**sensory memory** A memory store thought to hold onto incoming sensory information for very brief periods of time. A different sensory memory store is hypothesized for each sensory system.

**serial position effect** The phenomenon that items at the beginning or end of a list of items are more easily recalled than are items from the middle of the list.

**serial search** A search for information in which several stores or slots of information are sequentially examined to match to the target.

**short-term memory (STM)** A memory store thought to hold onto incoming information for up to 20–30 seconds. Also called "primary memory." It is thought to have a small capacity (up to 7 plus or minus 2 "slots").

**situated cognition** A belief that one's culture and one's everyday surroundings and tasks set both boundaries and possibilities for the cognitive tasks that are practiced and therefore strengthened in the normal course of daily living.

**size constancy** The phenomenon that one's perception of an object remains constant even as the retinal image of the object changes size (for example, because the object has moved closer or farther away from the perceiver).

**source-monitoring errors** An inability to remember the original source of a memory.

**space around the body** The area immediately around a person's body, in which the person can easily perceive and act on objects.

**space of navigation** Large spaces that people walk through, explore, or travel to and through.

**space of the body** Awareness of where the different parts of one's body are located at any given moment and what other objects different body parts are interacting with; used, along with internal sensations, to direct different parts of the body spatially.

**spacing effect** A phenomenon in which recall of material that is presented repeatedly is superior when the presentations are some time apart rather than immediately following one another.

**spreading activation** The excitation of one node in a semantic network by the excitation of another node to which it is connected; the excitation is said to flow across the connections.

**stage theories** Theories of development that postulate qualitatively different periods (stages).

**state-dependent learning** The phenomenon that recall is easier when the pharmacological state of the person at recall matches his or her pharmacological state during encoding.

**state-dependent memory** The phenomenon that material is easier to retrieve when the learner is experiencing the same state or context (for example, physical location, physiological state) that she or he was experiencing at the time of encoding. *See also* **encoding specificity.**

**STM** *See* **short-term memory.**

**storage** The mental "holding on" to information between the time it is encoded and the time it is retrieved.

**story grammar** A structure people are thought to use to comprehend large, integrated pieces of text. *See also* **schema** and **script.**

**strategies** Deliberate plans or routines used to carry out particular cognitive tasks.

**Stroop task** A task invented by J. R. Stroop in which a subject sees a list of words (color terms) printed in an ink color that differs from the word named (for example, *green* printed in blue ink). The subject is asked to name the ink colors of the words in the list and demonstrates great difficulty in doing so, relative to a condition in which non-color words form the stimuli.

**structuralism** One of the earliest schools of cognitive psychology. It focused on the search for the simplest possible mental elements and the laws governing the ways in which they could be combined.

**subjective contour** Illusory outline created by certain visual cues that lead to erroneous form perception. The existence of this phenomenon suggests that perception is an active constructive process.

**subjective probability** An intuitive estimate of the likelihood of occurrence of an event.

**subordinate level of categories** A hypothesized type of concept thought to make fewer distinctions than does a basic level concept.

**sunk cost effect** A bias in decision making in which already "spent" costs unduly influence decisions on whether to continue.

**superordinate level of categories** A level of categorization broader than the basic level, including exemplars that can be quite dissimilar from one another.

**syllogistic reasoning** Reasoning with problems concerning relationships among categories; for example, "All A are B; Some B are C; therefore, Some A are C."

**syntax** The arrangement of words within sentences; the structure of sentences.

**tachistoscope** An experimental apparatus that allows experimenters to present displays for a controlled and brief amount of time (for example, milliseconds). Sometimes called a *t-scope.*

**tacit knowledge** People's underlying and implicit beliefs about a task or event.

**tautology** A statement that is true by definition of its form (for example, "A is either true or it is false").

**template** A stored pattern or model to which incoming information is matched in order to be recognized and classified.

**temporal lobe** A division of the cerebral cortex located on the side of the head, involved in the processing of auditory information and in some aspects of memory.

**thalamus** A structure in the forebrain, involved in relaying information, especially to the cerebral cortex.

**thinking** A cognitive process used to transform or manipulate information that may be either focused (that is, solving problems with clear goals) or unfocused (that is, invoking loosely related ideas without clear purpose).

**top-down process** Cognitive (usually perceptual) process directed by expectations (derived from context, past learning, or both) to form a larger percept, concept, or interpretation. Also called *conceptually driven* or *theory-driven process.*

**truth table** A method of showing when compound logical expressions are true and when they are false by considering every possible assignment of truth values to propositions.

**typicality effect** The phenomenon in which experimental subjects are faster to respond to typical instances of a concept (for example, *robin* for the concept "bird") than they are to atypical instances (for example, *penguin*).

**unconscious processing** *See* **incubation.**

**utility** A measure of a person's happiness, pleasure, or satisfaction with a particular outcome.

**visual agnosia** An impairment in the ability to interpret (but not to see) visual information.

**visual image** A mental representation of a stimulus thought to share at least some properties with a pictorial or spatial depiction of the stimulus.

**visual search task** A task in which subjects are asked to detect the presence of a particular target against an array of similar stimuli.

**visuospatial sketch pad** The proposed component of working memory that maintains visual or spatial information.

**well-defined problem** A problem whose goals, starting information, and legal steps are stated explicitly.

**Wernicke's aphasia** Also called *receptive* or *sensory aphasia;* symptoms of this organic disorder include difficulty in understanding speech and producing intelligible speech, although speech remains fluent and articulate.

**Whorfian hypothesis of linguistic relativity** The idea that language constrains thought and perception, so that cultural differences in cognition could be explained at least partially by differences in language.

**within-subjects design** A research paradigm in which the same experimental subjects participate in different experimental conditions.

**word superiority effect** The phenomenon that single letters are more quickly identified in the context of words than they are when presented alone or in the context of random letters.

**working backward** A problem-solving technique that identifies the final goal and the steps, in reverse order, that are necessary to reach the goal.

**working memory (WM)** A memory structure proposed by Baddeley, described as consisting of a limited-capacity work space that can be allocated, somewhat flexibly, into storage space and control processing. It is thought to consist of three components: a central executive, a phonological loop, and a visuospatial sketch pad.

**X-ray computed tomography (CT)** *See* **computerized axial tomography scan.**

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# Author Index

Abelson, R. P., 257
Abramson, A., 353
Adamopoulos, J., 283
Adams, M. J., 321, 425
Aginsky, V., 86
Agnoli, F., 378
Ahn, W., 268
Ainsworth, K. A., 365, 569
Akshoomof, N. A., 37
Albert, J., 547
Allen, C., 338
Allen, C. K., 164
Allen, R., 418
Alloway, K. D., 37–41, 44, 46
Alpert, N. M., 324
Altmann, E. M., 165
Altmann, G., 359
Amabile, T. M., 413
Ambinder, M. S., 121
Amsel, A., 9
Anderson, D. R., 527
Anderson, J. R., 192, 250–252, 323, 440
Anderson, M. C., 191, 192
Andrade, J., 172, 173
Arkes, H. R., 473, 491
Armstrong, S. L., 273, 277
Ashcraft, M. H., 271, 272
Astington, J. W., 535
Atchley, P., 137
Atkinson, R. C., 24, 131, 147, 148
Atran, S., 574
Au, T. K., 378
Austin, G. A., 281
Averbach, E., 156
Ayduk, O., 296

Babcock, R. L., 549
Baddeley, A. D., 150, 153, 154, 158, 161, 165, 167, 169–173, 177, 179, 185, 196, 200, 201, 238, 278
Bahrick, H. P., 186–188
Baillargeon, R., 511, 514, 515
Ball, T. M., 310
Ballard, D. H., 27
Baltes, P. B., 550, 551
Bamberg, M., 189
Bandura, A., 462
Banerji, R., 399
Banich, M. T., 48, 50–52, 97–99, 124, 125, 127, 128, 380, 381
Bara, B. G., 437
Barad, V., 125
Barkley, R. A., 126
Barnes, J. M., 191
Barnett, T., 156
Baron, J., 381, 407, 430, 442, 464, 465, 483
Barrett, R. F., 174
Barsalou, L. W., 206, 274, 277, 279
Barston, J., 441
Bartlett, F. C., 202–204, 210, 255, 258, 278, 321, 369, 378
Barton, M. E., 292
Bass, E., 216
Bates, A., 156
Bates, E., 379
Baumann, R., 365
Beach, D. R., 519
Beach, L. R., 489
Becklen, R., 119, 121
Bekoff, M., 338
Belenky, M. F., 568, 569
Benbow, C. P., 562, 563
Bendixen, L. D., 390
Benfer, R. A., 411, 413
Benson, D. F., 97, 98
Berlin, B., 377
Berntsen, D., 209
Berry, J. W., 574, 578
Bhatt, R. S., 64
Bichot, N. P., 117
Biederman, I., 69, 70, 79, 303
Bierwisch, M., 346
Billings, F. J., 218
Bjorklund, D. F., 524
Black, I. B., 46
Black, J. B., 258, 290
Blakenship, S. E., 414
Blanchette, I., 441
Bleckley, M. K., 174

Block, J., 555
Bloom, A. H., 378
Blumber, C., 474
Bobbitt, B. L. 540, 541
Bobrow, D. G., 119
Boies, S. J., 541
Bomb, P., 527
Boot, W. R., 121
Born, D. G., 164
Bousfield, W. A., 194, 587
Bovet, M. C., 575, 576
Bower, G. H., 197, 200, 258, 290, 298, 301, 323
Bowerman, M., 517
Boyd, R., 28
Boyes-Braem, P., 274
Boyett-Anderson, J. M., 238
Braine, M. D. S., 446–448, 517
Brainerd, C. J., 512
Bransford, J. D., 201, 213, 214, 365, 366, 519
Brent, E. E., Jr., 411
Brewer, W. L., 136
Briand, K. A., 136
Briggs, G. E., 191
Bringmann, W., 189
Broadbent, D. E., 109, 110, 115, 116
Brooks, L. R., 286–288, 302, 303, 316
Brown, A. L., 519, 520, 534
Brown, E. L., 61
Brown, H. O., 374
Brown, J., 161
Brown, R. W., 15, 209, 517
Browne, B. A., 415
Bruce, V., 77
Bruner, J. S., 281–283, 285, 287, 288, 387, 591, 605, 608
Brunswik, E., 585
Brush, D., 64
Bryan, W. L., 133
Bryant, F. B., 478
Buchel, C., 454
Budiu, R., 250
Bugelski, B. R., 298
Bülthoff, H. H., 70
Bunting, M. F., 113, 174
Burns, B. D., 409, 410
Bush, E. S., 565, 566
Butterfield, E. C., 14
Butterworth, G. E., 534

Cabeza, R., 51, 77, 178, 220, 238
Cacioppo, J. T., 548
Caharack, G., 138
Campbell, D. T., 584
Campbell, J. I. D., 550
Campione, J. C., 519
Cannizzo, S. R., 519
Caplan, D., 380, 382
Carello, C., 93, 95
Carlson, L., 300
Carlson, N. R., 47, 49, 179
Carmichael, L., 321
Carpenter, P. A., 171, 256, 357, 361, 362, 367
Casat, C. D., 126
Case, R., 526
Casey, B. J., 41, 525
Catani, M., 382
Catlin, J., 271
Catrambone, R., 399
Cavanaugh, J. C., 549
Cave, K. R., 117
Ceci, S. J., 613
Ceraso, J., 430
Chabris, C. F., 121
Chambers, C., 361
Chambers, D., 312, 314
Chambers, K. L., 214
Chang, T. M., 255
Chapman, J. P., 476
Chapman, L. J., 476
Chapman, P., 104
Chapman, R. H., 436
Charness, N., 550
Chase, W. G., 406, 529, 530, 548, 549
Chater, N., 281, 382
Cheng, P. W., 446–448, 450
Cherry, E. C., 109
Chi, M. T. H., 405–407, 520, 530, 531
Chinsky, J. M., 519
Choi, I., 576, 598
Chomsky, N., 15, 16, 341, 344, 346, 515, 516
Christiansen, M. H., 382
Christou, C., 171
Clancy, S. A., 218
Clark, A., 255
Clark, E. V., 343
Clark, H. H., 339, 343, 364, 369
Clark, L. F., 363, 364
Clemen, R. T., 488
Clinchy, B. McV., 568, 569
Cofer, C., 587
Cohen, J., 556
Cohen, M. M., 354
Cohen, N. J., 125, 210, 221, 222, 224
Cole, M., 574, 582, 586, 587, 588, 592, 596, 597, 602, 604, 607–609
Collins, A. M., 240, 241, 244, 245, 248, 249, 435

Coltheart, M., 156
Conrad, C., 244, 245
Conrad, R., 164
Conway, A. R. A., 113, 174
Conway, L. G., III., 574, 579
Cooper, L. A., 305–308
Coriell, A. S., 156
Corkin, S., 395
Corrigan, B., 493
Corso, J. F., 549
Cosmides, L., 28, 29, 448, 449
Courshesne, E., 37
Cowan, N., 112, 113, 174, 175, 527
Cowper, E. A., 346
Cox, J. R., 439
Craik, F. I. M., 199–202, 549
Crowder, R. G., 157, 198, 199
Crundall, D., 104
Cruse, D. F., 415
Cuenod, C. A., 382
Cutting, J. E., 93

Dahan, D., 361
Damer, T. E., 430, 447
Daneman, M., 171
Dar, R., 511
Dara-Abrams, D., 328
Dark, V. J., 116
Dartnall, T., 413
Darwin, C. T., 12, 13, 157
David, B. 569
Davidson, W., 565
Davies, R. R., 238
Davis, H. D., 549
Davis, L., 216
Dawes, R. M., 493
Dawson, M. R. W., 493
Day, D., 547
Deaux, K., 563
Deffenbacher, K., 61
de Groot, A. D., 406, 548
de la Rocha, O., 29
DeLeonardis, D. M., 263
Dell, G. S., 238
Demakis, G. J., 478
DeMarie-Dreblow, D., 531
Demers, R. A., 337, 338
Demetriou, A., 171
Dempster, F. N., 526
Deregowski, J. B., 581, 586
DeRosa, D. V., 167
Desimone, R., 175
Desmond, J. E., 178
Detterman, D. K., 539
Deutsch, D., 115
Deutsch, G., 43, 46, 47, 52
Deutsch, J. A., 115
Devescovi, A., 379
Dewey, J., 417
Diamond, A., 525
Dolan, R. J., 454
Downey, G., 296
Doyon, C., 175
Drebus, D. W., 569
Dror, I., 558
Duncker, K., 397
Dunkle, M. E., 390
Durston, S., 525
Dweck, C. S., 565–567
Dyk, R. B., 545

Ebbinghaus, H., 189
Edwards, W., 460, 464, 466, 493
Eftekhari-Sanjani, H., 563
Egan, D. E., 394
Egeth, H. E., 136
Eich, E., 196, 197
Eichelman, W. H., 541
Eimas, P. D., 354
Elliot, E. M., 527
Ellis, A. W., 18
Engle, R. W., 174, 175
Enna, B., 565
Erickson, J. R., 439
Ericsson, K. A., 387
Ernst, G. W., 399
Etherton, J. L., 139, 140
Evans, A. C., 324
Evans, J. St. B. T., 436, 441

Fan, J., 126
Fancher, R. E., 6–8, 10, 13
Farah, M. J., 98, 99, 316, 318, 324, 325
Farr, M., 405
Faterson, H. F., 545
Fauth, J. M., 548
Feiden, C. P., 593
Feldman, J. A., 27, 64
Feltovich, P. J., 407
Ferrara, R. A., 519
Ffytche, D., H., 382
Fiddick, L., 449
Finger, K., 219
Finke, R. A., 309, 315–319, 321, 323, 415
Fischhoff, B., 477, 479, 491
Fivush, R., 531
Flavell, E. R., 532
Flavell, J. H., 11, 519, 520, 533–535

Fliegel, S. L, 318
Fodor, J. A., 41, 96, 374, 375
Fong, G. T., 446
Forkstam, C., 238
Fox, P. T., 91, 381
Franks, B. A., 523
Franks, J. J., 213, 214
Friberg, L., 324
Friedrichs, A. G., 531
Frisch, D., 488
Friston, K. J., 50
Frith, C. D., 50, 545
Fromkin, V., 342
Furbee, L., 411

Gabrieli, J. D. E., 178
Gal, F., 41, 42
Gallistel, R., 598, 599
Galotti, K. M., 239, 390, 424, 430, 434, 435, 438, 442, 455, 461–463, 484, 523, 569
Galton, F., 12, 13
Ganong, W. F. III., 239
Gardner, B. T., 338
Gardner, H., 16, 18, 80, 539–543, 544
Gardner, M. K., 431, 445
Gardner, R. A., 338
Garnham, A., 451
Garrett, M. F., 356–358, 360
Garry, M., 218
Gathercole, S. E., 177, 526
Gauthier, I., 84, 308
Gay, J., 586
Gazzanaga, M. S., 36
Gelade, G., 135
Gelman, R., 511, 598, 599
Gelman, S. A., 520–522
Gerhardstein, P. C., 308
Gernsbacher, M. A., 360, 382
Giard, M. H., 324
Gibbs, R. W., Jr., 350
Gibson, E. J., 70, 82, 83, 527, 528
Gibson, J. J., 31, 56, 59, 83, 93, 94, 95
Gick, M. L., 398, 399
Giedd, J. N., 41
Gigerenzer, G., 472
Gilligan, C., 568
Gilmore, R. O., 36
Ginsburg, H. P., 500, 503, 507, 511
Glaser, R., 405–407, 433
Glass, A. L., 79
Gleitman, H., 277
Gleitman, L. R., 277
Glenberg, A. M., 197
Glick, J., 523, 586
Globerson, T., 545
Glover, J. A., 300
Glucksberg, S., 271, 272, 373
Gobet, F., 406
Godden, D. R., 196
Goel, V., 407
Goetz, T. E., 565–566
Gold, B., 454
Goldberger, N. R., 568
Goldman, S. R., 364
Goldman-Rakic, P. S., 525
Goldsmith, R., 76
Goldstein, E. B., 76, 152, 176, 401
Gonon, M. A., 324
Goodenough, D. R., 545
Goodman, L. S., 375
Goodman, N., 280
Goodnow, J. J., 281
Goody, J., 602
Gorin, L., 534
Gould, S. J., 543
Graesser, A. C., 364
Grafman, J., 407
Gray, W. B., 274
Gray, W. D., 165
Green, B. L., 524
Green, F. L., 535
Green, K. E., 547
Greenberg, D., 210
Greenberg, S. N., 88
Greenfield, P. M., 578, 591, 592
Greeno, J. G., 394
Gregory, R. L., 61
Grice, H. P., 370, 371
Griggs, R. A., 439
Grimes, A., 64
Grossman, J. B., 534
Gruendel, J. M., 531
Guilbault, R. L., 478
Gustafson, M., 366, 367
Guynn, M. J., 196, 197

Haber, R. N., 157
Hafner, J., 418
Hahn, S., 136
Hahn, U., 280
Halford, G. S., 511, 512
Hall, C. R., 296
Hall, L. K., 175
Halle, M., 342
Hallett, D., 574
Halpern, A. R., 324
Halpern, D. F., 553, 556–558, 560, 562
Han, K., 544

Hanlon, C., 15
Harley, T. A., 338
Harnad, S., 354
Harris, P. L., 534
Harris, R. J., 351
Harter, W., 133
Hasher, L., 202, 255
Hatano, G., 593
Hauser, M. D., 338
Haviland, S. E., 363, 364
Hawkins, J., 523
Hay, J. F., 261
Hayes, N. L., 36
Haynes, V. F., 532
Healy, A. F., 88, 198
Hebb, D., 16, 179
Hedges, L. V., 555
Heider, E. R., 376
Heit, E., 279
Heller, W., 560
Henle, M., 445, 596, 597
Hennessey, B. A., 413
Hergenhahn, B. R., 10
Herrnstein, R. J., 542, 543
Herskovits, M. J., 584
Hillner, K. P., 7–9
Hirst, W., 137–139
Hismjatullina, A., 527
Hitch, G. J., 169, 170, 526
Hochberg, J. E., 93
Hockett, C. F., 337
Hodge, D., 219
Hodkin, B., 511, 512
Hoelzl, E., 478
Hoffman, R. R., 189
Hogan, H. P., 321
Holyoak, K. J., 398, 399, 431, 447
Hopkins, W. D., 338
Horn, J. L., 540
Hornsby, J. R., 591
Horton, D. L., 279
Houle, S., 454
Howe, M. L., 532
Hoyt, J. D., 533
Huan, D. B. M., 378
Hubel, D. H., 17, 68
Hudson, W., 580, 581, 591
Hume, D., 5
Hunt, E. B., 167, 378, 539, 541, 542
Husband, T. H., 219
Huttenlocher, J., 560
Hutton, U., 526
Hutzel, L., 474
Hyde, J. S., 555–557, 562, 564, 565
Hyman, I. E., Jr., 219, 220
Inagaki, K., 593
Ingram, D., 517–519
Ingvar, M., 238
Inhelder, B., 506
Intons-Peterson, M. J., 320, 321
Irwin, D. E., 136
Irwin, M. H., 592, 593

Jacklin, C. N., 551, 555, 556, 562
Jacoby, L. L., 261–263
James, W., 7, 8, 107
Jarvella, R. J., 357
Jaschinksi, U., 175
Jenkins, E., 532
Jenkins, J. M., 534
Jepson, C., 491
Ji, L., 576
Johansson, G., 93
Johnson, D. M., 274
Johnson, M. H., 36
Johnson, M. K., 255, 263, 365, 366
Johnson, N. S., 369
Johnson, W. A., 116
Johnson-Laird, P. N., 314, 348, 428, 437,
 450–452
Johnston, J. C., 136, 142
Johnston, W. A., 144–146
Jones, D. K., 382
Jones, R., 415
Jonides, J., 178
Just, M. A., 256, 357, 361, 362, 367

Kagan, J., 547
Kagitcibasi, C., 574
Kahneman, D., 117, 118, 467, 468, 470,
 471, 473, 474
Kail, R., 175, 526
Kalat, J. W., 38
Kamin, L. J., 543
Kane, M. J., 174
Kant, I., 6
Kanwisher, N., 325
Kapur, S., 454
Karlin, M. B., 200
Karp, S. A., 545
Kaschak, M. P., 382
Kato, T., 77
Kay, P., 377
Kearins, J. M., 589, 590
Keating, D. P., 540, 541
Keele, S. W., 76, 77, 284, 285, 257
Keenan, J., 362, 363, 369
Keeney, R. L., 493
Keeney, T. S., 520, 531
Keil, F. C., 279, 292

Kelley, C. M., 261
Kemler, D. G., 288, 259
Kemler Nelson, D. K., 288–290
Kempler, D., 381
Keppel, G., 163
Kerr, N. H., 317
Ketcham, K., 216
Kidd, E., 298
Kim, B. J., 598
Kim, I. J., 324
Kim, N. S., 268
Kimchi, R., 63, 64
Kintsch, W., 362, 363, 369
Kirchler, E., 478
Kirkpatrick, E. A., 298, 301
Kita, S., 378
Kitayama, S., 579
Kitchin, R. M., 326
Klaczynski, P. A., 548
Klassen, A., 144
Klatzky, R. L., 155, 298
Klebe, K. J., 549
Klein, G., 490
Klein, R., 187
Klein, R. M., 136
Kleinmuntz, B., 493
Kloo, D., 534
Knauff, M., 314
Koeske, R. D., 530, 531
Koffka, K., 10, 61, 62, 63
Kogan, N., 527, 545, 546
Kohler, W., 11, 61
Komatsu, L. K., 23, 276–278, 280, 292, 435, 523
Kopp, J., 484
Koriat, A., 88
Korsakoff, S., 259
Koslowski, L. T., 93
Kosslyn, S. M., 309–311, 316–319, 323–325, 558
Kozberg, S. F., 484
Kramer, A. F., 125, 136, 137
Krantz, D. H., 491
Kreiner, H., 88
Kubovy, M., 64
Kuhn, D., 525, 526
Kulick, J., 209
Kunda, Z., 491
Kung, H. F., 50

LaBerge, D., 125
Laboratory of Human Cognition, 603
Lachman, J. L., 14
Lamberts, K., 268
Landauer, T. K., 185, 197, 246
Lane, S. M., 213
Lang, B., 534
Lange, R., 283
Langley, P., 415
Lashley, K. S., 16, 46
Laughlin, P. R., 283
Lave, J., 29, 30, 611, 612
Lavin, B., 569
Lawrence, K. A., 298
Lea, G., 310
Legget, E. L., 565
Lehman, D. R., 447
Lerner, R. M., 551
Lesgold, A., 406, 407
Leslie, A. M., 534
Lettvin, J. Y., 68
Levin, D. T., 85, 86
Levine, S. C., 560
Levinson, S. C., 373, 378
Levy, J., 560
Lewis, J., 541
Li, P., 378
Lichtenstein, S., 479
Liddell, C., 582
Lin, E. L., 269, 279
Lindenberger, U., 550
Lindsay, D. S., 216
Linn, M. C., 555–557, 560
Linton, M., 197, 198, 204–207
Lipshitz, R., 490
Lisker, L., 353
Listen, C., 525
Liu, L. G., 378
Locke, J., 5, 6
Lockhart, R. S., 199, 201
Loftus, E. F., 212, 213, 216–219, 248, 249
Loftus, G. R., 154, 157
Logan, G. D., 126, 139, 140
Loring-Meier, S., 558, 560, 562
Lourenco, S. F., 560
Lubinski, D., 563
Luchins, A. S., 400
Luger, G. F., 252
Lunneborg, C., 541
Luria, A. R., 595, 604, 607
Lynch, E. B., 292

Maccoby, E. E., 555, 556, 562
Mace, W. M., 94
Mack, A., 87, 121
MacKay, D. G., 114, 115
MacLeod, C. M., 129
Magnuson, I. S., 361
Maier, N. R. F., 402
Malpass, R. S., 576, 578

Mandler, G., 194
Mandler, J. M., 369
Mansfield, A. F., 569
Markman, E. M., 520–522, 534
Markovits, H., 175
Marr, D., 81
Marslen-Wilson, W., 355
Martin, K. A., 296
Martindale, C., 27
Marvin, C., 544
Massaro, D. W., 88, 154, 156
Masuda, T., 582, 584
Mather, M., 213
Matlin, M. W., 63
Maturana, H. R., 68
Mayer, A. M., 220
McCandliss, B. D., 126
McCann, R. S., 142
McClelland, J. L., 26, 88, 253–255
McCloskey, M. E., 210, 271, 272
McCullogh, W. S., 68
McDermott, K. B., 218
McDonald, J. E., 88
McDonald, K., 338
McDowd, J. M., 549
McGaugh, J. L., 226, 227
McGee, M. G., 557
McGeoch, J. A., 190
McKoon, G., 238
McLaughlin, D. H., 592
McNally, R. J., 218
McNamara, A. F., 198
McNeill, D., 16
McRae, K., 255
Medin, D. L., 268–270, 272, 278, 279, 291, 292, 574
Meehan, A. M., 563
Meehl, P. E., 492
Melton, A. W., 198
Menon, V., 238
Merril, E., 250
Mervis, C. B., 248, 271–274, 276, 278
Metzler, J., 304, 307
Meyer, D. E., 242, 244, 246
Meyer, E., 324
Michaels, C. F., 93, 95
Michalski, R., 435
Milhan, M. P., 125
Mill, J. S., 5
Miller, G. A., 15, 71, 159, 160, 352, 373
Miller, J. L., 348
Miller, K. F., 600–602
Miller, P. H., 500, 503, 505, 511–513, 532
Miller, R. S., 271
Mills, C. B., 279
Milner, B., 177
Mintun, M. A., 381
Mischel, W., 296
Mitchell, T. R., 489
Miyake, A., 172
Miyamoto, Y., 582
Miyashita, Y., 324
Moates, D. R., 342
Montello, D. R., 326, 328
Moray, N., 109, 110, 156, 157
Morelock, M. J., 563
Morita, S. K., 213
Moritz, S. E., 296
Moshman, D., 510, 523
Moyer, R. S., 303
Mozer, M. C., 100
Munakata, Y., 36
Murdock, B. B., 152, 153
Murphy, G. L., 269, 279, 291
Murray, C., 542, 543
Murray, D. J., 5, 10
Murtaugh, M., 29, 30
Myers, K. M., 609

Nairne, J. S., 177, 202
Naus, M. J., 519
Neath, I., 151, 154, 156, 158, 161, 191
Neely, J. H., 191, 192, 244
Neimark, E. D., 436
Neisser, U., 2, 31, 70, 96, 119, 121, 137, 138, 155, 156, 157, 204, 210, 269, 277, 316
Nelson, K., 531
Nelson, S., 565
Nevarez, G., 121
Newcombe, N. S., 511, 560
Newell, A., 387, 393, 407, 411
Newsome, S. L., 88
Nicely, P., 71
Nickerson, R. S., 321
Nilsson, N. J., 408
Nisbett, R. E., 431, 447, 472, 491, 576, 582, 584, 598, 613
Nolde, S. F., 263
Norenzayan, A., 576, 598, 613
Norman, D. A., 115, 119, 151, 162, 163, 255, 257
Nowakowski, R. S., 36, 525
Nugent, L. D., 527
Nyberg, L., 51, 178, 238

Oakes, J., 565
Oakhill, J., 451, 452
Oberauere, K., 175
O'Brien, E. J., 291
Obusek, C. J., 355
Ochsner, K. N., 324

O'Craven, K. M., 325
Oda, M., 77
Oliver, L. M., 447
Olkin, I., 555
Olton, R. M., 415
Olver, R. R., 591
Opper, S., 500, 503, 507, 511
Orasanu, J., 490
Orne, M. T., 320
Ornstein, P. A., 519
Ortony, A., 256
Osherson, D. N., 446, 522
O'Sullivan, J. T., 531
Owens, J., 258

Paivio, A., 296, 297, 300, 304
Palmer, S. E., 79
Papp, K. R., 88
Pascual-Leone, J., 526
Pashler, H. E., 107, 110, 115, 116, 127, 136, 139, 140, 149
Patterson, R. D., 105
Payne, J. W., 488
Pea, R. D., 523
Pearson, D. A., 126
Pellegrino, J. W., 433
Peng, K., 576
Perfect, T. J., 238
Perkins, D. N., 401, 414, 415, 418, 419, 452
Perky, C. W., 316
Perner, J., 534
Péronnet, F., 324
Perry, D. W., 324
Petersen, A. C., 91, 560
Petersen, S. E., 381, 382
Peterson, L. R., 161
Peterson, M. J., 161
Peterson, T., 250
Petersson, K., 238
Petty, R. E., 548
Pezdek, K., 218
Phillips, D., 479
Phillips, L., 151
Phillips, W., 547
Piaget, J., 11, 12, 501–511
Pickering, S. J., 526
Pickrell, J. E., 216, 217, 219, 220
Pillemar, D., 209, 210
Pinker, G., 6
Pinker, S., 308, 311
Pitman, R. K., 218
Pitts, W., H., 68
Platsidou, M., 171
Ploof, W. H., 126

Pollard, P., 441
Pomerantz, J. R., 64
Poortinga, Y. H., 576, 578
Posner, J., 599
Posner, M. I., 50, 65, 125, 126, 139, 178, 284, 285, 287, 380–382, 541
Postman, L., 151, 191
Premack, D., 338
Price, J. R., 261
Pritchard, T. C., 36, 38–41, 44, 46
Provitera, A., 430
Pullum, G. K., 376
Putnam, H., 291, 292
Pylyshyn, Z. W., 96, 319–321, 323

Quillian, M. R., 240, 241, 244, 245, 248, 249
Quinlan, P. T., 136
Quinn, P. C., 64, 515

Radford, A., 345
Raichle, M. E., 50, 65, 91, 125, 178, 380–382
Rao, S. M., 220
Rasch, B. H., 378
Ratcliff, R., 238
Rayner, K., 361
Read, J. D., 216
Reaves, C. C., 138
Reber, A. S., 285–287
Reder, L. M., 192, 250
Reed, E. S., 94
Reed, S. K., 399
Reich, L. C., 591
Reicher, G. M., 87
Reimer, R. L., 569
Reingold, E. M., 261
Reisberg, D., 312, 314
Reiser, B. J., 310, 446, 318
Reiss, A. L., 238
Reitman, J. S., 164, 165
Remington, R. W., 142
Rensink, R. A., 84, 86
Revlis, R., 438
Riby, L. M., 238
Richards, A., 441
Richards, D. D., 593
Richerson, P. J., 28
Rips, L. J., 245, 425, 429, 445
Rivers, W. H. R., 584
Rizzella, M. L., 291
Roazzi, A., 613
Robinson, J. A., 206
Rodler, C., 478
Rodman, R., 342

Roediger, H. L., III., 196, 197, 218, 258, 260
Rogoff, B., 513
Roland, P. E., 324
Rollock, D., 547
Rosch, E., 246, 271–274, 276, 376
Rosenthal, R., 553
Rosman, B. L., 547
Rosnow, R. L., 553
Ross, B. H., 197
Ross, J., 298
Ross, L., 472
Ross, M., 468, 469
Ross, N. O., 574
Roth, D., 511
Roth, E. M., 277
Rubens, A. B., 97, 98
Rubert, E., 338
Rubia, K., 126
Rugg, M. D., 51
Rumain, B., 446
Rumelhart, D. E., 28, 88, 254–257
Runco, M. A., 413, 417
Ruthruff, E., 136, 144
Ryan, M. K., 569

Sabini, J. P., 430
Sachs, J. S., 358
Sacks, O., 100
Sakamoto, S. O., 417
Salas, E., 490
Salthouse, T. A., 549
Saults, S., 527
Savage-Rumbaugh, S., 338
Saxe, G. B., 599
Schacter, D. L., 176, 218, 220, 237,
  238, 258–262
Schafer, G. N., 593
Schaller, M., 574
Schank, R. C., 257
Scharchar, R. J., 126
Schatzberg, A. F., 238
Schmidt, H., 135
Schmidt, S., 210
Schneider, W., 130–133
Schraw, G., 359
Schroeder, D. H., 514
Schultze, R., 175
Schumacher, G. M., 342
Schuwartz, S. P., 283
Schvaneveldt, R. W., 88, 241, 244
Schwartz, S. H., 404
Schwartz, S. P., 292
Scribner, S., 523, 574, 582, 588, 592,
  596, 597, 602, 604–611
Searle, J. R., 349, 350
Secco, T., 364
Sedlmeier, P., 472
Segall, M. H., 574, 584–586
Segman, J., 298
Selfridge, O. G., 73
Sells, S. B., 430
Sereno, S. C., 361
Sevcik, R. A., 338
Sharnks, D., 268
Sharp, D. W., 586, 592
Sharpnack, H., 64
Shaw, R. E., 94
Shea, D. L., 563
Shepard, R. N., 295, 301, 304, 305, 307
Shiffrin, R. M., 24, 130–133, 139, 151, 169, 198
Shimura, A. P., 177, 260
Shoben, E. J., 245, 277
Sicoly, F., 468, 469
Siegel, L. S., 511, 512
Siegler, R. S., 500, 532, 593
Simon, H. A., 387, 388, 393, 406, 407,
  411, 529, 530, 548, 549
Simoneau, M., 175
Simons, D. J., 85, 86, 121, 122
Simpson, C., 271
Skinner, B. F., 10
Skyrms, B., 425
Slackman, E. A., 531
Slayter, C., 484
Slone, M., 511
Smith, A., 126
Smith, C. M., 600
Smith, E. E., 178, 245, 246,
  271–278, 288, 598
Smith, J. D., 288
Smith, S. M., 374, 414, 415
Smullyan, R., 424
Snyder, A. Z., 91, 92
Snyder, C. R. R., 139
Solomon, K. O., 292
Spanoudis, G., 171
Spelke, E. S., 137, 138, 527
Sperling, G., 154–158
Spiers, M. V., 36, 50, 52
Springer, S. P., 43, 46, 47, 53
Spurzheim, J., 42
Squire, L. R., 224
Stacy, E. W., Jr., 79
Stanley, J. C., 22, 562, 563
Stanovich, K. E., 548
Stark, K., 191
Staudinger, U. M., 550
Stavy, R., 593

Steedman, M., 437
Stefik, M., 413
Stein, B. S., 201
Sternberg, R. J., 415, 431, 433, 443–446, 539
Sternberg, S., 165, 167
Stevenson, H. W., 602
Stollery, B. T., 238
Stover, W. B., 176
Strauss, N. L., 565
Strayer, D. L., 144–146
Stroop, J. R., 128, 129
Strutt, G. F., 527
Su, R., 250
Suess, H., 175
Suppes, P., 426
Surprenant, A., 151, 154, 156, 158, 161
Swanson, K. L., 206
Swinney, D. A., 359, 375

Tanaka, J., 84
Tanenhaus, M. K., 361
Tannok, R., 126
Tarr, M. J., 56, 64, 70, 84, 86, 308
Tarule, J. M., 568
Tavris, C., 553
Taylor, R. L., 541
Taylor, S. E., 139
Teasdale, J. D., 172, 173
Terrace, H. S., 338
Tetlock, P. E., 491
Thaler, R. H., 473
Theeuwes, J., 136, 137
Thomas, K. M., 41
Thompson, W. L., 324
Thomsen, D. K., 209
Thomson, D. M., 193, 195
Thorndyke, P. W., 368, 369
Tkacz, D., 167
Todd, P. M., 254
Tolman, E., 10
Toman, J. E. P., 374
Tooby, J., 28, 29, 449
Toth, J. P., 261
Tottenham, N., 525
Towse, J. N., 526
Trabasso, T., 364
Treisman, A. M., 111, 114, 115, 135
Triandis, H. C., 573
Tsal, Y., 135, 136
Tulving, E., 179, 194, 195, 200–202, 235–239
Turing, A., 17
Turner, M. E., 445
Turner, T. J., 258, 290
Turvey, M. T., 94, 157
Tversky, A., 467, 468, 470, 471, 473, 474, 488
Tversky, B., 311, 326–328
Tweed, R. G., 574
Tyler, L. E., 545, 547

Underwood, B. J., 191
Underwood, G., 104, 163

van den Broek, P. W., 364, 366, 367
Van Der Wege, M. M., 339, 369
Varnhagen, C. K., 364
Villa, D., 213
Voelz, S., 523
Vollmeyer, R., 409, 410
von Winterfeldt, D., 460, 464, 466, 493
Vygotsky, L. S., 513, 595, 602, 603

Wade, C., 553
Wade, K. A., 218
Wagner, A. D., 178, 220
Walter, A. A., 321
Waltz, J. A., 456
Wang, S., 514
Ward, T. B., 415
Warren, R. M., 355
Warren, R. P., 355
Warrington, E. K., 259, 262
Wason, P. C., 426, 434, 439
Watkins, M. J., 157
Watkins, O. C., 157
Watson, J. B., 9, 10, 374
Watt, I., 602
Waugh, N. C., 151, 162, 163
Wax, N., 593
Weaver, C. A., III., 210, 211
Webb, A., 125
Webb, R. M., 563
Weisberg, R. W., 415
Weiskrantz, L., 259, 262
Weiten, W., 403
Welford, A. T., 144
Well, A. D., 527
Wellman, H. M., 534
Wells, G. L., 214
Welsh, A., 355
Welton, K. E., Jr., 76
Wentura, D., 175
Wernicke, C., 380
Wertheimer, M., 10, 61, 417
West, R. F., 548
Whittlesea, B. W. A., 261

Whorf, B. L., 375–379
Wible, C. G., 210
Wickens, D. D., 106, 164
Wiesel, T. N., 17, 68
Wilhelm, O., 175
Williams, G. B., 238
Williams, J. H., 556, 557
Williams, P., 84
Wilson, B. G., 609
Winston, P. H., 28, 408
Witkin, H. A., 545
Wittgenstein, L., 272
Wittman, W. W., 175
Wober, M. 613
Woloshyn, V., 263
Wood, N. L., 112, 113
Woods, S. K., 126
Woodworth, R. S., 430
Woody-Ramsey, J., 532
Wszalek, T., 125
Wulfeck, B., 379
Wundt, W., 20

Xu, Y., 394
Xuereb, J. H., 238

Yantis, S., 136
Young, A. W., 18
Yuille, J. C., 214, 302

Zacks, R. T., 202
Zaragoza, M. S., 214
Zatorre, R. J., 324
Zelnicker, T., 545, 547
Zhang, H., 600
Zhao, Z., 178
Zhu, J., 600
Zimmer, J. W., 298

# Subject Index

Abilities, cognitive. *See* Abilities, mental
Abilities, mental, 13
  cross-cultural differences in, 573, 582, 588
  development of, 510, 514, 520, 522
  gender differences in, 551–569
  individual differences in, 539–545
  *See also* Intelligence
Ablation, of brain, 46
Accommodation of mental structures, 501–502
Achievement motivation, 565–567
Acquiring prototypes, 284, 285
ACT* model, of memory, 250–252
Adaptation of mental structures, 501
Affirming the consequent, fallacy, 428
Affordance, 95
Aging, effects of, 549–551
Agnosia, visual. *See* Visual agnosia
Ambiguity, 276, 348
  lexical, 358–360
  phonetic, 358
  syntactic, 358, 359
Amnesia, 175, 220–227
  anterograde, 175, 221–223
  retrograde, 175, 223–226
Amygdala, brain structure, 39, 41, 220, 227
Analogical reasoning. *See* Reasoning, analogical
Analytic processing of information, 529
Anchoring, in decision making, 473, 474
Anomaly, semantic, 348
Antecedent, in sentence comprehension, 364
Antisaccade task, in executive functioning, 174
Aphasia, 43, 380
  Broca's (expressive), 43, 380
  Wernicke's (receptive), 380
Apperceptive agnosia, 97–100. *See also* Visual agnosia
Arbitrariness, characteristic of language, 337
Aristotle, 5
Artifacts, 292
  in experiments, 378
  as a kind of concept, 292
Artificial intelligence, 17, 336
Assertive, speech act, 349
Assimilation of mental structures, 501, 502
Association, 6
Associative agnosia, 99. *See also* Visual agnosia
Attention, 3, 104–146
  attentional capture, 106, 136–137
  Attention Deficit Hyperactivity Disorder (ADHD), 126, 127
  automization hypothesis of, 139, 140
  cell phone usage and, 144–146
  defined, 3
  development of, 527, 528
  divided, 107, 137–145, 263
  Kahneman's model of, 117, 118
  and language, 341
  and memory, 170, 173, 174, 341
  networks of visual, 125, 126
  neuroscientific studies of, 123–128
  selective, 107–123
  visual, 125
Attenuation theory, of attention, 114, 115
Auditory sensory memory. *See* Echo
Autobiographical memory, 204–207
Automatic encoding, 202
Automaticity. *See* Automatic processing
Automatic processing
  in attention, 128–133
  of language, 375
  in memory, 202
  in perception, 65
  in reasoning, 423
Availability heuristic, 467–469

Backtracking, problem-solving strategy, 394–396
Bartlett, Sir Frederick, 202–204, 210, 255, 258, 278, 321, 369, 381
Base rates, in decision making, 470
Basic level of categorization, 274
Bayes's theorem, 465
Behaviorism, 9, 14, 18, 296
Believability effect, in reasoning, 439, 441
Between-subjects design, 21–22
Bias, 442. *See also* Cognitive illusions; Confirmation bias; Framing effects; Hindsight bias; Illusory correlation; Overconfidence
Bilateral, in brain function, 46
Binaural presentation, in dichotic listening task, 108
Bottleneck, attentional, 116, 142, 144
Bottom-up processes, 64–78

Boxes-and-arrows, model of cognition, 25
Brain imaging, 47–52. *See also* Computerized axial tomography; Functional magnetic resonance imaging; Magnetic resonance imaging; Positron emissions tomography
Brain stem, 36–37
Brain structures, 36–41
Bridging inferences, 364
Broca's area (of brain), 380, 381
Brown-Peterson task, 161–164
Bug detector cells, in feature analysis, 68

Calibration curve, 480
Capacity, 24, 239, 503, 539, 565, 576
  attentional, 116, 117
  defined, 116
  of memory systems, 159, 160, 168, 169, 184, 185, 526, 527
Carpentered world, 584
Categorical perception (of speech), 353, 354
Categorical syllogism, 429, 452, 453
Categorization, 269, 274–281
  cross-cultural studies of, 590–595
  development of, 509
  in inductive reasoning, 430
  as memorial strategy, 194, 300
Category, 269, 274–281
  basic level, 274
  coherence of, 280, 281
  constraints around, 276
  subordinate level(s), 274
  superordinate level(s), 274
Category size effect, in semantic memory experiment, 246
CAT scan. *See* Computerized axial tomography
Centered thinking, 506
Central executive, in working memory, 170
Cerebellum, 37, 175
Cerebral blood flow, 50, 178, 238, 324
Cerebral cortex, of brain, 39–41, 185
Change blindness, 84–87
  laboratory demonstration, 85
  real world version, 85
Characteristic feature, of concept, 270–272
Chimpanzees, and language, 338, 339
Chomsky, Noam, 15, 16, 341, 344, 346, 515, 516
Chunking, 160, 173, 549
Circular reactions, 505
Classical conditioning, 9
Classical view of concepts, 281–292
Classification. *See* Categorization
Classifying new instances, 257–269
Clinical interview, 21
Cocktail party effect, 110
Coding, 160, 161, 184, 185, 199, 227
  in memory, 159–161, 168, 185
Cognition, everyday. *See* Everyday cognition
Cognitive abilities, 539–545
Cognitive architecture, 252
Cognitive development, 497–535
  non-Piagetian approaches to, 512–524
Cognitive economy, principle of, 240, 244, 280
Cognitive flexibility, 611
Cognitive illusions, in decision making, 466–481
Cognitive neuropsychology, 18, 22
Cognitive overload, 460
Cognitive processes, 2, 3
  acoustic, 200, 201
  attentional, 104–146
  automatic, 128
  conceptual, 269, 281, 549
  controlled, 133, 134
  creative, 413–417
  data limited, 118, 119
  in decision making, 459
  development of, 498–535
  domain specificity of, 374
  in ecological framework, 29–31
  examples of, 3, 5, 6
  gender differences in, 554–565
  individual differences in, 538–569
  informationally encapsulated, 374, 375
  in information-processing framework, 24–26
  language, 337
  memorial, 149–179
  modular, 374
  parallel, 26, 133
  perceptual, 56–100
  reasoning, 422–456
  resource limited, 118, 119
  schematic, 202
  semantic, 235–255
  serial, 26, 133
  shallow, 200
  in thinking, 417–419
Cognitive psychology, 2–32
  cross-cultural approaches to, 573–613
  current trends in, 17, 18, 526
  defined, 2
  historical roots of, 5, 6, 17
  paradigms of, 24–31
  research methods of, 19–23
Cognitive revolution, the, 14–17
Cognitive science, 17
Cognitive style, 545–548, 565
  gender differences in, 565
Cognitive tempo. *See* Impulsivity; Reflectivity
Coherence (of a category). *See* Category, coherence of
Commissive, speech act, 350
Common sense knowledge, 237
Communication, difference from language, 337

Communications engineering, 15
Communication system, 337–339
Competence, 341, 514, 590
Componential approach to reasoning, 442–446
Comprehending text passages, 360–367
Computerized axial tomography (CAT), 47, 48, 381
Computer metaphor, 17, 28, 250, 443
Computer science, 17, 31
Concentration. *See* Attention
Concept, 268, 269, 292
Concept attainment, 281–284
Conceptual constraints. *See* Category, constraints around
Conceptual development, 520–522
Conceptual peg, in dual coding hypothesis, 301
Concrete-operations stage of cognitive development, 509
Confidence, of memory, 212, 219
Confirmation bias, 433, 478, 479
Connected knowing, 242–245, 568, 569
Connectionism, 26–28
  network, 27
  processing units, 26
Connectionist approach to cognitive psychology, 26–28
Connectionist model of semantic memory, 252–255
Connectionist model of word and letter perception, 88–91
Conscious experience. *See* Consciousness
Consciousness
  in attention, 108, 118, 130, 133, 137
  control processes and, 169, 170
  in recall, 262, 263
Conservation, Piagetian, 507–509, 599
Conservative focusing, in concept attainment, 283
Constituent, linguistic, 344
Constructive nature of long-term memory, 200–220
Constructivist approach to perception, 93, 96
Content effect, in reasoning, 439, 441
Context effect, 79, 196, 360
  conceptual, 277
  in decision making, 473
  in memory, 196
  in perception, 79. *See also* Top-down processing
  in reasoning, 449
  in text comprehension, 354–356
Context sensitivity, 579
Contradiction, 427, 522
Contrary recognition, 415
Controlled observation, 21, 31
Controlled processing, 129, 133, 134, 168
Conversation, production and comprehension of, 369–373, 452, 531
Corpus callosum, of brain, 39, 47
Counterexamples, in reasoning, 433, 452
Counterfactual inference, 378
Counting
  cross-cultural studies of, 598–602
  principles of, 599
Creative solutions, finding, 413–417
Creativity, 413
Critical thinking, 417–419
Cross-cultural studies of cognition, 573–613
Crypt arithmetic problems, 393
Cue overload, in memory, 197
Cultural context, of cognition, 573
Cultural relativism, 576–578
Cultural syndrome, 574
Cultural universality, 576–578
Culture, 573, 574, 576

Darwin, Charles, 13
Darwinian theory of evolution, 8, 415
Data-driven processes. *See* Bottom-up processes
Daydreaming. *See* Thinking, unfocused
Decay, of memory trace, 161, 163, 165, 171, 189, 190
Decentered thinking, 509
Decision making, 3, 460
  improving, 491–493
  phases of, 461–464
  and reasoning, 443, 446
Decision structuring, 463
Declaration, speech act, 350
Declarative memory, 250, 252, 258, 260
Deductive reasoning. *See* Reasoning, deductive
Deductive validity, 425, 510
Deferred imitation, 505
Demand characteristics, 319–321
Denying the antecedent, fallacy, 428
Dependent variable, 21
Descartes, Réne, 6, 16
Descriptive models of decision making, 481, 488–490
Dewey, John, 8, 417
Diagnosis, and categorization, 268
Dichotic listening task, 108–116, 156, 174
  attended message, 108
  unattended message, 108–116
Digit span task, 160, 520, 526
Directed remembering, 415
Directive, speech act, 350
Direct perception, 92–96. *See also* Perceptual equivalence
Discourse comprehension, 258, 278, 338, 351. *See also* Conversation, production and comprehension of
Discreteness, characteristic of language, 337
DISENGAGE, operation of attention, 126, 127
Distal stimulus, 57, 92
Divided attention. *See* Attention, divided
Domain-specific problem-solving strategies, 390
Dual-coding hypothesis of memory, 300, 301
Dual task performance, 106, 137, 144–146

Early selection, theory of attention, 110
Ebbinghaus, Hermann, 189, 197, 202, 211
Echo, 154, 156–158
Ecological approach to cognitive psychology, 29–31
Ecological validity, 19
ECT. *See* Electroconvulsive therapy
Education, formal, effects of, 591–595, 602–608
EEG. *See* Electroencephalography
Effect size (*d*), 555
Egocentrism, in cognitive development, 506
Electroconvulsive therapy, 223, 224
Electroencephalography (EEG), 52, 127
Elimination by aspects, in decision making, 488
Empiricism, 6
Encoding
  automatic, 202
  in cognitive development, 527–529
  defined, 151
  in long-term memory, 194–197
  in reasoning, 437, 444, 445
  specificity, 194–197
  variability, 197
ENHANCE, operation of attention, 126
Entailment, semantic, 348
Episodic memory, 204, 236–239, 260
Ethology, 501
EU. *See* Expected utility
Evaluating, phase of decision making, 464
Event-related potential (ERP), 52, 127
Everyday cognition, 3
  in categorization, 267, 288
  in decision making, 473, 490
  examples of, 118
  in language, 459
  in long-term memory, 184, 208, 211, 215, 256, 257
  in perception, 79, 85, 86
  in problem solving, 576, 595, 604
  in reasoning, 434, 435
  in thinking, 386, 388, 394, 415–417
Evolutionary approach to cognitive psychology, 28, 29
Executive functioning, 41
Exemplar, 277, 278, 280, 285
Exemplar view of concepts, 277, 278
Exhaustive search, in short-term memory, 167
Expectancy effects, 553
Expected utility (EU), 482
Expected utility theory, 481–483
Expected value, 481, 482
Experimental control, 20, 21
Experimenter expectancy effects, 320, 553
Experimenter expectations. *See* Experimenter expectancy effects
Experiments, 21, 22, 31
  in attention, 108, 109, 119–122, 124, 125, 127–132, 135–138, 140–142
  in categorization, 274, 275, 281–287, 289–291
  in cognitive development, 507, 508, 514, 517, 519, 521, 526, 528, 530
  cross-cultural studies, 575–577, 580–594, 596–601
  in decision making, 474, 475, 484–488
  defined, 21–22
  in imagery, 299–311, 312, 314, 318, 321–323, 328–330
  in individual differences, 541, 547, 549–551, 556, 562
  in knowledge representation, 240, 241–244, 247, 258–261
  in language, 352–357, 359, 361–366, 371, 381
  in memory, 186, 187
  in problem solving, 408–412
  in reasoning, 437–438
  situated cognition, 609–613
Expertise, effects of, 66, 134
  in categorization, 276, 281, 283–286, 288
  and cognitive development, 529, 530
  in problem solving, 548, 549
Expert/novice differences, 405–407, 548, 549
Expert system, 411, 413
Explanation-based view of concepts, 280
Explicit memory, 258–264
Expressive, speech act, 350
Eye fixations, 361
Eye-mind hypothesis of reading comprehension, 361
Eyewitness memory, 211–214

Faculty psychology, 41
Fallacies, in reasoning, 428, 449, 450
False belief task, 534
False fonts, 91
False memories, 214–220
Familiarity judgement, 263
Family resemblance, of concepts, 272, 273, 289
Fan effect, of memory 192
Featural analysis, in perception, 68–75
Feature
  characteristic, 245
  conceptual, 270, 271
  defining, 245, 270, 283, 289
  necessary. *See* Feature, defining
  perceptual, 68, 71–75, 83, 88, 135, 520
  phonemic, 341
  sufficient, 245, 270, 283, 289
Feature comparison model, of semantic memory, 245–248
Feature detectors, 68, 73, 86
Feature generation task, 273, 274
Feature integration theory, of perception, 135, 136
  illusory conjunctions, 135, 136
Field dependence, cognitive style, 545, 546
Field independence, cognitive style 545, 546
Filter theory, of attention, 109–113
Flashbulb memories, 207–211

Flowcharts, 25
fMRI. *See* Functional magnetic resonance imaging
Focused thinking, 387, 423
Forebrain, 36, 38–41
Forgetting, 151
  from long-term memory, 186–194
  from short-term memory, 140, 161–165
Forgetting curves, 186, 188, 189
Formal operations stage of cognitive development, 510
  gender differences in, 555
Forming new concepts, 281–292
Form perception, 59, 61
Four-card task, in propositional reasoning, 428
Framing effects, in decision making, 472, 473. *See also* Context effects
Free-recall task, 586–588
Frontal lobe, of brain, 39–41, 124, 177, 525
Functional fixedness, in problem solving, 402
Functionalism, 7, 8, 11, 18, 31
Functional magnetic resonance imaging (fMRI), 50, 57, 178, 325, 382, 454

Galton, Sir Francis, 12, 13, 18
Gamblers' fallacy, 470–472
Garden path sentences, 358
Gathering information, phase of decision making, 462
Gender differences, 551–569
Generalized event representations (GERs), 531
General problem solver (GPS), 393
Generate-and-test strategy, of problem solving, 390–392
Generative grammar, 16. *See also* Grammar
Genetic epistemology, 11, 12
Geon, 69, 70
Gestalt principles of perceptual organization, 62–64
  law of Pragnanz, 63, 64
  principle of closure, 63
  principle of common fate, 63
  principle of good continuation, 62
  principle of proximity, 62
  principle of similarity, 62
Gestalt psychology, 10, 11, 18, 31, 62, 64
Gibson, James J., 31, 56, 59, 83, 93–95
Gibsonian theories of perception, 277
Gist, in perceptual encoding, 86
  in recall, 363
Given-new strategy, of sentence comprehension, 363, 364
GPS. *See* General problem solver
Grammar, 337–340
Gricean maxims of cooperative conversation, 369–373

Hebb rule, for learning, 179
Helpless achievement motivation, 565–567
Hemineglect, 124. *See also* Sensory neglect
Heuristic, 312, 468
Hierarchical semantic network model, 240–245
Hindbrain, 36, 37
Hindsight bias, 476–478
Hippocampus, of brain, 38, 39, 41, 220, 226
Holistic processing of information, 527
Horizontal–vertical illusion, 584–585
Human factors engineering, 14
Hume, David, 5
Hypothalamus, 38, 39
Hypotheses, 433
Hypothesis testing, 433, 434

Icon, 154–156
Ill-defined problem, 389
Illusory conjunctions, in perception, 135, 136
Illusory correlation, in decision making, 474, 476
Images
  auditory, 296
  cutaneous, 296
  mental picture metaphor, 295, 311, 317
  olfactory, 296
  strategic, in decision making, 489
  trajectory, in decision making, 489
  value, in decision making, 489
  visual, 10, 13, 295–330, 540
Image theory, of decision making, 489, 490
Imaginal scanning, 309–314
Immediacy assumption of text processing, 361
Implicit encoding, principle of visual images, 315
Implicit information, in reasoning task, 413
Implicit knowledge, 236, 340, 364, 513
Implicit learning, of concepts, 285–290
Implicit memory, 236, 258–264
Impulsivity, 546, 547
Inattentional blindness, 120–123
Incidental learning task, 200
Incomplete or incorrect representations, of problems, 402–405
Incubation, 414, 415
Independent variables, 21
Individual differences, 12, 538–569
Inductive reasoning. *See* Reasoning, inductive
Inductive strength, of an inference, 425
Inference
  bridging, in text comprehension, 364
  counterfactual, 378
  in everyday reasoning, 435
Inference rule
  in expert systems, 411
  in inductive reasoning, 431
  in propositional reasoning, 427
  in syllogistic reasoning, 430
Informationally encapsulated process, 374
Information-processing approach, to cognitive psychology, 24–26, 28, 239
  in cognitive development, 513, 522

Insight, 413, 416
Instrumental conditioning, 9
Integration, of information, 167, 456, 468, 493
Intellectual structures. *See* Mental structures
Intelligence, 539–545
  development of, 500–502
  multiple, 543–545
  tests, construction of, 555
Intentional processing. *See* Controlled processing
Interacting-images, mnemonic technique, 298, 299, 302
Interference, in memory, 161, 163–165, 190, 191
Introspection, 7, 20, 388
Invariance, perceptual, 96

James, William, 7, 8, 107

Kant, Immanuel, 6
Knowledge acquisition components, as cognitive processes, 445
Knowledge base, in problem solving
  development of, 29–532
Knowledge-based view of concepts, 279–281
Knowledge representation, 3

Laboratory experiments. *See* Experiments, laboratory
Language, 3, 26
  acquisition, 516–519
  and cognition, 373
  comprehension, 351–373
  difference from communication, 337
  neuropsychological views, 379–382
  production, 356, 357, 369–373
  speech perception, 351–356
  structure of, 339–351
  universals, 516
Language acquisition device (LAD), 516
Lateralization, of brain function, 46, 47, 380
Late selection theory, of attention, 115, 116
Law of small numbers, in decision making (fallacy), 471, 472
Levels of processing
  approach to memory, 198–202
  in word perception, 88, 89
Levels of representation, 17
Lexical ambiguity, 359
Lexical decision task, 242
Lexical insertion rules, 346
Lexicon, 240
Limited-capacity processing, 15
Linear models, of decision making, 492
Linguistic competence, 341
Linguistic performance, 341
Linguistic relativity, 375–379
Linguistic rules, 346. *See also* Gricean maxims; Phonological rules; Pragmatic rules; Syntactic rules
Linguistics, 15, 345–347, 350, 378, 517
Literacy, 602–608
Localization of function, in brain, 16, 41–46
Locke, John, 5, 6
Logic, 423, 425, 436, 447, 563
Logical connectives, 426
Logical necessity. *See* Deductive validity
Long-term memory, 151, 184–194
  capacity, 184–185
  coding, 185
  encoding, 194
  forgetting, 187–194
  retention curves, 188, 189
  retention duration, 186, 198
  retrieval of information, 194–198
  and short-term memory, 184, 198
Long-term potentiation, 179
Long-term storage. *See* Long-term memory
LTM. *See* Long-term memory
Luria, Alexander R., 595, 604, 607

Magnetic resonance imaging (MRI), 48, 49, 382
Making a final choice, phase of decision making, 463, 464
Man-who arguments, in decision making, 472
Masking, 156
Mastery-oriented achievement motivation, 565–567
Material implication, in propositional reasoning, 426
Mathematical ability, 562–565
Maturation, as developmental mechanism, 501, 524–526, 532
MAUT. *See* Multiattribute utility theory
Maxim of manner, 371, 373
Maxim of quality, 371, 372
Maxim of quantity, 371, 372
Maxim of relation, 371, 373
Means–ends analysis, problem-solving strategy, 392–394
Mediation (in memory), 201, 299
Memorial strategies, preschoolers' use of, 519, 520
Memory, 3, 4
  and attention, 170, 173, 174, 341
  autobiographical, 204–207
  capacity, 159, 160, 168, 169, 184, 185, 526, 527
  consolidation, 226, 227
  cross-cultural approaches, 586–590
  decay, 161
  and decision making, 169
  defined, 3
  development of, 519, 520, 526, 527
  directed, 415
  episodic, 235
  executive functioning in, 174, 175

  explicit, 258–261
  eyewitness, 211–213
  false, 214–220
  flashbulb memories, 207–211
  for general knowledge, 233–264
  implicit, 58–261
  and individual differences, 541, 550
  and knowledge representation, 279
  and language, 341, 374
  long-term. *See* Long-term memory
  mechanisms, 210
  metaphors of, 151–154
  and mnemonics, 194
  narrative, 202–204
  neurological studies of, 175–179
  real world, 202, 204–210
  reconstructive nature, 202–220
  repressed, 216
  semantic, 238
  sensory, 151,154–158
  short-term. *See* Short-term memory
  state dependent, 194
  stores, 151
  systems, 237
  target, 192
  trace, 161
  for traumatic events, 215
  working. *See* Working memory
Memory codes, 297–302
Memory consolidation, 226, 227
Memory set, 131, 132, 166, 167
Memory span in cognitive development, 526, 527
Mental dictionary. *See* Lexicon
Mental effort. *See* Attention
Mental energy. *See* Attention
Mental imagery. *See* Visual imagery
Mental-models approach to reasoning, 442, 450–454
Mental representation, 10, 14
  conceptual, 268, 277, 287
  development of, 503, 506
  icon, as type of, 155
  and imagery, 295, 297, 319
  and knowledge representation, 239, 250
  in memory, 160, 207, 217
  in perception, 93
  in problem solving, 404, 405
  in reasoning, 456
  in text comprehension, 361
Mental rotation of visual images, 304–309, 560, 561
Mental search, thinking as, 408, 409, 443
Mental set, 399, 400
Mental structures, 501
Meta-analysis, 555, 556
Metacognition, 533, 535
  experiences, 534
  knowledge, 533
Metacomponents, as cognitive processes, 445
Method of loci (mnemonic technique), 296, 297
Mill, John Stuart, 5
Mnemonics, 194, 295, 297–302
Modal theory of memory, 151, 183, 197
Modularity hypothesis, of language, 374, 375
Modus ponens, inference rule, 426, 429
Modus tollens, inference rule, 426, 429, 435
Mood-dependent memory effect, 197
Morpheme, 339
Morphology, 339
Motivation, for cognitive tasks, 565, 568
MOVE, operation of attention, 126, 127
MRI. *See* Magnetic resonance imaging
MUckraker (expert system), 411
Müller-Lyon illusion, 584
Multiattribute utility theory (MAUT), 484–488
Multiple intelligence (MI), theory of, 543–545

Narrative memory, 202–220
Narrative review, 555
Nativism, 6
Naturalistic observation, 19–20, 31
Natural-kind concepts, 292
Natural selection, 13
Necessary feature. *See* Feature, necessary
Need for cognition, 548
Network model of semantic memory, 248
Networks, attentional, 104
  visual, 125, 126
Networks, prepositional. *See* Semantic network
Neural network, 26
Neuroimaging. *See* Brain imaging
Neurological maturation, 523–526
Neuropsychological investigations
  of attention, 123–128
  of cognitive development, 524–526
  of imagery, 324, 325
  of individual differences, 560
  of language, 379–382
  of memory, 175–179
  of perception, 91
  *See also* Brain imaging
Neuroscience, 17
Nine-dot problem, 401
Nominal-kind concepts, 292
Nonanalytic concept formation. *See* Implicit learning, of concepts
Nonstage theories of cognitive development, 499
Normative models of decision making, 481
Noticing, as creative process, 415

Object permanence, 504
Occipital lobe, of brain, 39, 41
Optic flow, 94
Organization, of concepts, 269
Organization, of knowledge
  and concepts, 269
  development of, 530
  individual differences in, 541
  and visual images, 300
Organization, of mental structures, 502
Overconfidence, in decision making, 479–481, 491

Paired-associates learning, task, 190
Pandemonium, model of perception, 73, 74
Paradigm, 24
Parallel cognitive processes. *See* Cognitive processes, parallel
Parallel distributed processing (PDP), 26
Parallel search, in short-term memory, 166
Parietal lobe, of brain, 39–41, 123, 124
Parsing, 58, 114, 368, 374
Partial-report technique, in iconic memory experiment, 155
Pattern recognition, 3, 58–100
Pavlov, Ivan, 9
Pegword method (mnemonic technique), 299
Percept, 58, 98
Perception, 3, 56–100
  and attention, 104
  auditory perception, 71
  and categorization, 276
  cross-cultural studies of, 579–586
  and decision making, 466, 473
  defined, 3
  development of, 507, 509
  disruptions of, 97–100
  Gestalt approaches to, 59–64
  and language, 355, 356, 377
  and memory, 154, 158
  model for the perception of letters, 73, 74
  of pictures, 580–584
  and speech, 351–356
  and visual imagery, 305, 308, 316
Perceptual cycle, 96
Perceptual development in infancy, 514–515
Perceptual equivalence, principle of visual images, 316
Perceptual illusions, 475
Perceptual learning, 82–84
Perceptual matching task, 541
Perceptual set, 400
Performance, linguistic, 341
Performance components, as cognitive processes, 445
Permastore, in memory, 184, 185
Permission schema, in propositional reasoning, 447, 448
Person–machine system, 14
PET. *See* Positron emissions tomography
Philosophy, 22, 417, 424, 501
Phoneme, 69, 339–343
Phoneme restoration effect, 355. *See also* Context effect
Phonetics, 341
Phonological loop, in working memory, 171
Phonological rules, 343
Phonology, 339, 341–343
Phrase-structure rules, 346
Phrenology, 42
Phylogenic division, of the brain, 36–41
Piaget, Jean, 12, 18, 500–512, 514, 515, 527, 535
Piagetian theory of cognitive development, 12, 500–512, 514, 515, 524, 535, 563
  general principles of, 501–512
  reactions to, 511, 512
Pictorial literacy, 580–584
Picture metaphor, in visual imagery, 321–322
Pivot grammar, 517
Planning, 176, 446, 506
Plasticity, of brain, 41, 46
Plato, 5, 6, 151, 602
Play, fantasy, development of, 506
Pointillism, in top-down processing, 82
Pons, of brain, 36, 37
Positron emission tomography (PET), 50, 178, 324, 381, 382, 454
Practical logic, 447
Practice, effects of, in attention, 128
Pragmatic rules, 370
Pragmatics, 339, 349–351
Prefrontal cortex, of brain, 41, 525
Premise meaning, 436–438
Premises, of reasoning task, 422, 436–440
Preoperational stage of cognitive development, 12, 505–509
Preposing, syntactic transformation, 345, 346
Prescriptive models of decision making, 481
Presupposition, in language comprehension, 423
Primacy effect, in free recall, 153
Primal sketch, in perception, 81, 82
Primary circular reactions, 505
Primary memory. *See* Short-term memory
Primary somatosensory cortex, of brain, 44, 46
Priming, 114. *See also* Semantic priming; Repetition priming
Proactive interference, 163, 174, 190
Probability, 464–466
  objective, 466
  subjective, 466
Probe digit task, 162

Problem solving, 3, 386
  blocks to, 399–407
  classic problems, 390–399
  individual differences in, 540, 549, 556–565
  and reasoning, 445, 454
Problem space hypothesis, 407–411
Procedural memory, 250, 258, 260
Process dissociation framework, 261–264
Processing speed, 526, 540, 550
Production deficiency, of strategy, 532
Production rules, 251
Productivity, property of language, 337
Proposition, 250
Propositional complexity, in text comprehension, 363
Propositional reasoning. *See* Reasoning, propositional
Propositional theory of visual imagery, 323, 324
Prosaccade task, in executive functioning, 174
Prosopagnosia, 99–100
Prototype, 75, 272, 284, 285
Prototype matching, model of perception, 75–78
Prototype view of concepts, 272–277
Proximal stimulus, 57, 92, 93, 98
PRP. *See* Psychological refractory period
Psychological essentialism, 291, 292
Psychological refractory period (PRP), 140–144

Quantitative abilities, 562–564
Quasi-experiments, 22

Rationality, 460
Reasoning, 3
  analogical, 396–399, 423, 431–433
  approaches to the study of, 442–454
  cross-cultural studies of, 595–598
  deductive, 424–429
  development of, 522–529
  everyday, 434, 435
  formal, 434, 435
  individual differences in, 562–565
  inductive, 424, 431–434
  neuropsychological evidence of, 454–456
  patterns of recognition performance, 436–442
  propositional, 426–429
  syllogistic, 429, 430, 451–453
  types of, 424–435
Reasoning by analogy, problem-solving strategy, 396–399
Rebus, in problem solving, 414
Recall, 3
  autobiographical, 204–207
  defined, 3
  and knowledge representation, 233, 236–238, 261
  from long-term memory, 186, 188, 190, 194, 197, 198
  mnemonics as aid to, 297–302
Recency effect, 153
Recoding, 17, 156, 160
Recognition, 3
  defined, 3
  in memory, 196, 213
  of objects/stimuli, 61, 115, 133
Recognition-by-components, model of perception, 70–71
Recognition-primed decision making, 490
Reconstruction, memory. *See* Constructive nature of long-term memory
Recovered memories, 215–220
Reflective abstraction, 510
Reflective thinking. *See* Critical thinking
Reflectivity, 546, 547
Reflexes, as precursors to mental schemes, 501
Regularity, property of language, 337
Rehearsal, 153, 519
Relational-organizational hypothesis, of memory, 301, 302
Release from proactive interference, 164
Remembering. *See* Memory
Repetition priming, 259
Representations, 17. *See also* Mental representation
Representativeness heuristic, 469–472
Repression, 216
Research design. *See* Research methods
Research methods. *See* Clinical interviews; Controlled observation experiments; Meta-analysis; Naturalistic observation; Neuropsychological investigations; Quasi-experiments
Resources, cognitive, 105
Response selection, 140, 142
Retention, memorial, 149, 161–165
Reticular formation, of the midbrain, 28
Retina, 57
Retinal image, 57, 93
Retrieval, 149, 166, 167
  organization of knowledge and, 277
  in problem solving, 456
  in reasoning, 443
Retrieval cue, 192
Retroactive interference, 191
Reversibility, in thinking, 507, 509
Rewrite rules. *See* Phrase structure rules
Rules/heuristics approach to reasoning, 96, 202, 255–258

Scanning images, 309–314
Schema/schemata, 96, 202, 255–258, 366, 367, 501
  for concepts, 278, 279, 290
  for events, 202–204
  in perception, 96
  for problem solving, 398
  for reasoning, 448
Schemata/scripts view of concepts, 278, 279
Schema theory of attention, 119, 120

Scheme (Piagetian), 501
Schooling, effects of, 588, 591, 592, 602–608
Scientific method. *See* Research methods
Script, 257, 290, 291, 367, 531
    as conceptual representation, 290, 291
    development of, 290, 291
    in narrative memory, 219
    and story grammars, 367–369
Secondary circular reactions, 505
Secondary memory. *See* Long-term memory
Selection task, 428. *See also* Four-card task
Self-contradiction, 348
Self-terminating search, in short-term memory, 166
Semantic memory, 201, 236–255
Semantic network, 241
Semantic priming, 244, 255, 259, 271
Semantic relations, in language acquisition, 517–519
Semantics, 348, 349
Semiotic function, in cognitive development, 506
Sensorimotor stage of cognitive development, 503–505
Sensory memory, 151, 153–158
Sensory neglect, 124
Sensory register, 57
Sentence comprehension, 357–360
Sentence verification task, 241, 244, 245, 271
Separate knowing, 568
Serial cognitive processes. *See* Cognitive processes, serial
Serial position effect, in free recall, 153
Serial reproduction, 200
Serial search, in short-term memory, 166
Series completion task, 431
Setting goals, phase of decision making, 462
Shadowing. *See* Dichotic listening task
Short-term memory, 151, 153, 159–168
    capacity, 159, 160, 168
    coding, 159, 161, 168
    and long-term memory, 184, 198
    retention duration, 161–165
    retrieval of information in, 165–167
Short-term storage. *See* Sensory memory
Similarity-based view of concepts, 280
Simultaneous scanning, 282
SIT. *See* Stimulus-independent thoughts
Situated cognition, 609–613
Size constancy, 58
Skills, 499, 511, 513, 549, 554–556, 588, 607
Skinner, B. F., 10
Socioecnomic status (SES), in individual differences, 560–562
Socrates, 602
Somatosensory cortex, of brain, 41
Source monitoring, in memory, 263
Spacing effect, in long-term memory, 197
Spatial cognition, 326–330
    space around the body, 326
    space of the body, 326
    space of navigation, 327
Spatial equivalence, principle of visual images, 316, 317
Spectogram, 352–354
Speech act theory, 350
Speech errors, 356, 357
Speech perception, 357, 358
Spotlight, attentional, 116, 117
Spreading activation, principle of, in semantic memory, 243, 248
Stage theories of cognitive development, 499–511
Standardized tests, 431, 563, 564
State-dependent learning, 197
Stimulus-independent thoughts, 172
STM. *See* Short-term memory
Storage, memory. *See* Memory stores
Story grammar, 367–369
Story recall, 203
Stranger anxiety, in cognitive development, 504
Strategies, 532
    conceptual, 281–284, 288
    development of, 499, 532
    memorial, 160, 519, 520
    problem-solving, 431, 439, 603
    in reasoning, 454
    *See also* Backtracking; Generate-and-test; Means and ends analysis; Reasoning by analogy
Stroop task, 128, 129
Structural equivalence, principle of visual images, 317–319
Structuralism, 6, 7, 11, 18, 28
Structuring the decision, phase of decision making, 462, 463
Subjective contours, 61
Subordinate level of categorization, 274
Sufficient feature, 270, 283, 289
Suffix effect, in echoic memory, 157, 158
Suggestibility, 216
Sunk cost effect, 474
Superior colliculus, structure of brain, 37, 38
Superordinate level of categorization, 282
Syllogisms, 429, 430, 434, 436–439, 441, 442, 446, 452–454, 523, 540
Syllogistic reasoning. *See* Reasoning, syllogistic
Symbolic-distance effect, in imagery, 303
Synapse, 185
Synonymy, semantic, 348
Syntactic rules, 340–347, 516–519
Syntax, 339, 343–347, 516

Tacit knowledge, 319
Target detection task, 140
Tautology, 427, 522

Template, 66–68
Template matching, model of perception, 65–68, 75, 76, 78
Temporal lobe, of brain, 39–41, 175, 176, 238
Tertiary circular reactions, 505
Text comprehension, 360–367
Text recall. *See* Story recall
Thalamus, of brain, 38, 39
Theories, as mental explanations, 279
Theory-driven processes. *See* Top-down processes
Theory of mind, development of, 534
Think-aloud protocols, 388, 394, 398, 414, 418
Thinking, 386–419
  abstract, 510
  centered on perception, 507
  decentered, 509
  and decision making, 460, 474
  development of, 522
  focused, 387
  hypothetical, 522
  and language, 378
  methods of solution, 390–399
  practical, 609–613
  and reasoning, 422
  unfocused, 387
Thorndike, Edward, 8
Titchner, Edward, 7, 23
Tolman, Edward, 10
Top-down processes, 64, 79–88, 137, 525
Towers of Hanoi problem, 393, 408, 549
Transformational equivalence, principle of visual images, 317
Transformational rules, 346
Translation, 173
Tree diagram, 344–347
Truar/liar puzzles, 428, 429
Truth conditions, of sentence, 349
Truth tables, 427
Truth value, of proposition, 426, 427
Tumor problem, 396–398
Turing, Alan, 17
2-4-6 task, 439, 442
Two-string problem, 402, 403
Typicality, of concept, 271, 272, 276
Typicality effect, 245, 246, 249, 271, 272, 276

Unattended message, in dichotic listening task, 108–115, 119, 201
Uncertainty, in decision making, 459, 460
Unconscious processing, 414, 415
Underconfidence, in decision making, 420
Unfocused thinking, 387
Unilateral neglect, 100
Universality, of theory, 499
Universal machine, 17
Utility, 481–483
Utility models of decision making, 481–488

Verbal abilities, 556, 557
Verbal protocols. *See* Think-aloud protocols
Verbatim recall, 206, 258
Visual agnosia, 97–100
  apperceptive agnosia, 98
  associative agnosia, 99
Visual cortex, 100, 324, 325
Visual illusions, 584–586
Visual imagery, 13, 295–330
  critiques of research and theory, 319–324
  empirical investigations of, 302–314
  nature of, 315–324
  neuropsychological findings, 324, 325
  picture metaphor, 321, 322
  principles of, 314–319
Visual search task, 70
Visual sensory memory. *See* Icon
Visual-spatial abilities, 557–562
Visual-spatial memory, 588–590
Visuo-spatial scratch pad, in working memory, 171
Vote counting, 555
Vygotsky, Lev, 513, 595, 602, 603

“War of the Ghosts,” story, 202–204, 210, 369
Watson, John B., 9, 10, 374
Well-defined problem, 388, 389
Wernicke’s aphasia, 44, 380
Wernicke’s area (of brain), 43, 380, 381
Whole-report condition, in iconic memory experiment, 155
Whorfian hypothesis of linguistic relativity. *See* Linguistic relativity
Within-subjects design, 22
Word advantage. *See* Word superiority effect
Word perception, models of, 88–91
Word superiority effect, 87, 88, 244
Working backward, problem-solving strategy, 394
Working memory, 153, 169–175, 198, 199, 250, 252, 550
  and amnesia, 221, 222
  in cognitive development, 526, 527
Wundt, Wilhelm, 6–8, 20

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